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The Canadian Entomologist

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The Canadian Entomologist

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Woodpeckers as Predators of the Codling Moth in Nova Scotia[1]

By C. R. MacLellan[2]

There have been few quantitative studies on the role of woodpeckers in control of insect pests. Hutchison (1951) and Wygant (1958) pointed out the importance of these predators in reducing outbreaks of the Engelmann spruce beetle and Knight (1958) established a means of assessing the value of woodpeckers by correlating their activity with beetle survival but made no attempt to measure the numbers of woodpeckers in an area.

In 1953 a program was begun to study the effect of natural control agents on numbers of the codling moth in Nova Scotia. It was shown by MacLellan (1958) that woodpeckers seek and find, by sight and touch, more than 50 per cent of the overwintering codling-moth larvae on tree trunks. Since then further insight into the mechanism of control exerted by woodpeckers has been obtained and the results are presented here.

Methods

Sampling Codling-Moth Populations

It is comparatively easy to sample codling-moth populations quantitatively because the codling moth overwinters as a mature larva under the rough scales of bark on the trunks and larger limbs of apple trees. An estimate of the number of larvae susceptible to attack by woodpeckers was made by counting the larvae on one vertical foot of tree-trunk surface on each of six randomly selected trees per orchard. The amount of predation by woodpeckers in this sample was determined by counting the characteristic holes made in the cocoons by the woodpeckers. Cocoons made by larvae of a previous generation may be identified by their brittle texture and weathered colours and were not included. However, cocoons older than two years were seldom found on young, fast-growing trees.

The Number of Woodpeckers and Territorialism

Estimates of the numbers of woodpeckers presented a more challenging problem. Early in the study it was suspected that woodpeckers maintained a permanent territory or feeding zone throughout the year, but attempts to trap and mark them to study this habit were unsuccessful. The species, sex, and frequency of occurrence of woodpeckers in 60 study orchards were recorded for the years 1953-1958. The hairy woodpecker, *Dendrocopos villosus villosus* (Linnaeus), and the northern downy woodpecker, *Dendrocopos pubescens medianus* (Swainson), were the only species known to feed on the codling moth in any of the sampling areas during the time the larvae were vulnerable to attack. Where too few woodpeckers were seen to estimate their numbers with a reasonable degree of precision the data were not used. As a further check on the visual counts corrugated cardboard bands (see later) and the bark of apple trees were examined for beak marks during 1956-58.

The behaviour and territorialism of woodpeckers was studied in two 800-acre census areas. The more wooded area "A" consisted of 555 acres of mixed deciduous and coniferous trees, chiefly secondary growth of birch, poplar, beech,

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maple, spruce, hemlock, pine, and fir; 165 acres of orchard; and 80 acres of arable fields, new orchard plantings, and pasture. Area "B" consisted of 40 acres of sparsely distributed copses of mixed deciduous and coniferous trees, chiefly secondary growth of poplar, beech, maple, spruce, and fir; 275 acres of orchard; and 485 acres of arable fields, new orchard plantings, and pasture. In addition area "B" had a number of large isolated elm, maple, oak, and willow shade trees. Two types of sampling were used in estimating the woodpecker population in the census area; the criteria in the two methods were: sight records of woodpeckers in the first, chiefly qualitative method, and evidence of feeding in the second, quantitative method. In the former method the areas were first covered by random walks and later by walks along lines established on a grid pattern. Woodpeckers were detected occasionally by sight but more frequently by their calls or tapping and scraping noises on the trees and subsequently identified to species and sex. The location of each observed woodpecker was plotted on maps of the areas. These data strongly suggested separate feeding zones for each pair.

A more quantitative method was then devised to define more precisely the limits of the feeding zones. The wooded parts of the areas were traversed east and west along lines spaced 50 yards apart. In stations of approximately 200 square yards and at 50-yard intervals ten standing dead trees, five dead limbs, and five dead trees or limbs lying on the ground were examined for signs of recent and older evidence of woodpecker activity. When necessary, standing dead trees were felled for close examination. The presence of fresh wood chips flicked onto the ground by the woodpeckers aided in the selection of the dead wood in the sampling stations. Each tree or limb attacked was given a score of one. Corrugated-cardboard bands four inches wide and 13 inches long containing small pellets of beef suet and paraffin wax, which were previously found to be readily attacked by woodpeckers, were used to find the limits of the feeding zones in the orchards. The bands were placed on the trunks or larger branches of apple trees in stations of approximately 1,600 square yards (one-third acre) or in lines radiating from the centres of certain feeding zones.

Woodpeckers begin to search for codling-moth larvae in apple orchards in late July but most of the feeding occurs in the fall. Activity declines in late December and is slight throughout the winter and spring months. The sight-record method of taking a census was used for three consecutive seasons, each lasting from September to May, and the feeding-activity method was used in late September, 1958. No attempt was made to count the numbers of woodpeckers during the breeding season.

Results and Discussion

Determination of the Feeding Zones

In area "A" 263 sight records of woodpeckers were made and 138 in area "B". When plotted on maps of the areas the sight records of the birds indicated five feeding zones containing nine hairy woodpeckers and eight feeding zones containing 14 northern downy woodpeckers for the more wooded area "A". In the sparsely wooded area "B" there were two and three feeding zones containing four hairy and six northern downy woodpeckers, respectively. In area "A" a female hairy and a male and a female northern downy woodpecker were solitary. There was no indication of separate feeding zones for individuals of a pair; both the male and female were observed throughout the zones. In no case were two males or two females of the same species seen together in one zone.

The feeding zones established by determining feeding activity corroborated the data for the sight records, and accurately defined the limits of the zones.

With one exception, only the bands within the feeding zones were attacked. The bands radiating from the centres of the feeding zones were less frequently attacked as the distance from the centre increased. The most concentrated feeding always occurred in the centre of the zone but secondary concentrations were found throughout and occasionally occurred near the peripheries. The secondary concentrations were associated with food supply. Trees were rarely attacked outside the defined feeding zones. The fact that feeding outside of the zones did occur, however, indicated either that a resident woodpecker occasionally foraged outside its regular feeding zone or that a transient was in the area.

There was an average of three woodpeckers per 100 acres in area "A" and 1.3 per 100 acres in area "B". In the breeding season Morris *et al.* (1958) found up to ten hairy woodpeckers and a smaller number of downy woodpeckers per 100 acres of forest during a spruce-budworm outbreak in New Brunswick and Yeager (1955) found as many as four downy and hairy woodpeckers per acre during an outbreak of the Engelmann spruce beetle in Colorado. The availability of food during the winter months probably limited the numbers of woodpeckers in the present census areas.

The feeding zones in the census areas were generally oval in shape and in area "A" averaged 77 acres for the hairy and 39 acres for the northern downy woodpecker whereas in area "B" the average sizes were 102 and 60 acres, respectively. The zones overlapped between species but not within species.

Attempts to attract woodpeckers into an orchard with beef suet in coconut shells placed near and throughout the orchard, but outside the nearest feeding zone, failed. In one orchard, beef suet placed on the periphery of the nearest feeding zone attracted a woodpecker beyond its usual limits where it fed on codling-moth larvae. This woodpecker was not seen nor were signs of its predation on codling-moth larvae observed in the orchard until suet was made available in each of the three years of the experiment.

Predation of Codling Moth

In the 60 orchards regularly examined each spring during 1954-58, the number of cocoons spun by codling moth larvae in the preceding season ranged from 0 to 82 with an average of 9.9 per six vertical feet of tree-trunk surface. It seemed unlikely that such low populations would attract woodpeckers to any degree but they were active in all but one of the study orchards. Yeager (1955) did not determine whether the high populations of woodpeckers found in Colorado were due to reproduction or to concentration but Knight (1958) stated that woodpeckers concentrated in small areas where the beetle occurred in outbreak numbers. In the present study the records of the older signs of woodpecker feeding activity indicated that the feeding zones were permanently established with no suggestion of concentration in the census areas. During the study the physical structure of these areas did not change nor did outbreaks of pest insects occur to cause woodpeckers to concentrate. Similarly, no major change in conditions took place in the vicinity of any of the study orchards.

Where the codling-moth population is at or below an average of 12 larvae per six vertical feet of tree-trunk surface and natural control agents are active, experience in Nova Scotia has shown that insecticides need not be used. When the codling moth is below this level in spring the natural control agents usually keep damage to the fruit by the next generation of the pest below an economic level. Woodpecker predation is more intense in orchards having high codling-moth populations but such predation may not be sufficient to reduce the pest population to the desired level. Woodpeckers alone reduce overwintering larval

TABLE I.

Transformation of means of Codling moth data grouped to show results of predation by one to four woodpeckers preying upon overwintering codling moth larvae. K = 50 (arbitrary number).

Number of woodpeckers P	Mean number of codling moth vulnerable to attack N_O	Mean number of codling moth larvae attacked N_A	$\frac{PK}{PK - N_A}$	$\ln \frac{\frac{PK}{PK - N_A}}{PN_O}$
1	7.5	2.0	1.042	0.00238
	13.5	5.5	1.124	0.00376
	18.5	6.3	1.144	0.00316
	25.0	8.0	1.190	0.00302
2	3.4	1.7	1.017	0.00108
	7.1	3.3	1.034	0.00102
	12.6	5.7	1.060	0.00100
	23.5	13.9	1.161	0.00138
3	5.5	2.5	1.017	0.00044
	10.0	4.7	1.032	0.00046
	15.0	8.0	1.056	0.00053
	37.0	24.7	1.197	0.00070
4	4.1	2.9	1.015	0.00039
	9.6	5.6	1.029	0.00032
	13.7	8.1	1.042	0.00033
	39.3	26.6	1.153	0.00039

populations to the tolerable level in 17 of a possible 24, 7 of 12, 25 of 30, 11 of 16, and 5 of 6 orchards for the years 1954-58 respectively.

Thirty-three of the study orchards were classified according to woodpecker density. Table I shows the transformation required for rectilineation of the means of the numbers of codling-moth larvae attacked by woodpeckers at densities of one to four using Watt's (1959) sub-sub-model:

$$N_A = PK\,(1-e^{-aN_O P^{1-b}}) \qquad (1)$$

which for the purpose of obtaining estimates of parameter values can be transformed to:

$$\ln\left[\frac{\ln \frac{PK}{PK - N_A}}{PN_O}\right] = \ln a - b \ln P$$

where P is the number of predators, N_o the initial number of prey vulnerable to attack, N_A the number of prey attacked, and K the maximum number of prey that can be taken per predator during the time the prey is vulnerable. Since the range of values for the prey was not great enough for an accurate calculation of K, an arbitrary value of 50 was assigned to it. That is, 50 codling moth larvae is the estimated maximum number that one woodpecker takes per season per six vertical feet of tree trunk; this number is relative to the density of the prey as found during the study.

The data have been grouped for clarification in Fig 1 to show the relation of predation to prey density.

If equation (1) is valid, then it follows that:

$$\ln\left(\frac{PK}{PK - N_A}\right) = a\,N_O\,P^{1-b},$$

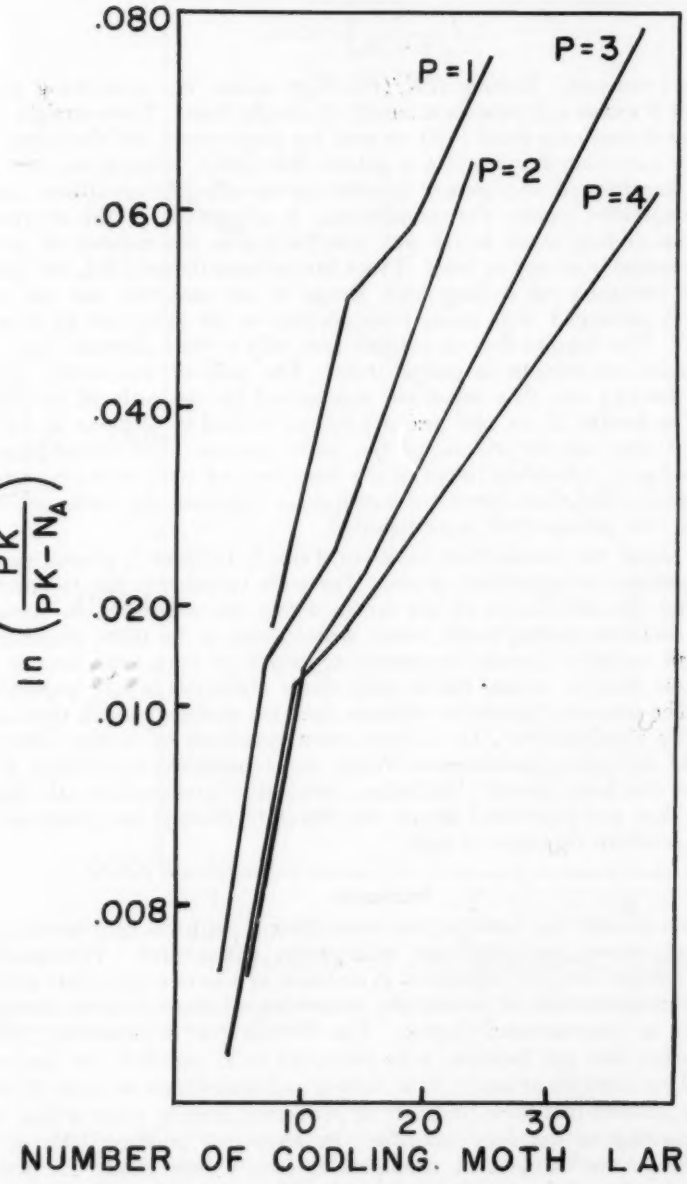

Fig. 1. The relation of the number of codling moth larvae vulnerable to attack by one to four woodpeckers to the ln PK/(PK − N_A) where K is equal to 50. As the number of woodpeckers increases from one to four, the number of larvae taken per individual woodpecker decreases with an increase in prey numbers.

or for a given P value,

$$\ln\left(\frac{PK}{PK - N_A}\right) = C\,N_O, \qquad (2)$$

where C is a constant. Plotting $(PK/(PK\text{-}N_A))$ against N_o on semi-log papers for different P values will produce a family of straight lines. These straight lines must all pass through the point (1,0) on semi-log graph paper, and the slopes will decrease for increasing P values if *b* is greater than unity. Here *b* is a constant measuring the effect of woodpecker numbers on the effect of predation. Intraspecific competition among the woodpeckers is suggested by the decreasing predation on codling moth larvae per woodpecker as the number of woodpeckers increased from one to four. From late summer to early fall, the period of greatest predation on codling-moth larvae, it was observed that the male woodpeckers prevented their mates from feeding in the same tree by chasing them away. The females flew to another tree only a short distance away but the males made no attempt to pursue them. The male of the smaller species (northern downy) also flew off when approached by the male of the larger species. The females of the two species appeared to feed in harmony as did the male of the one and the female of the other species. This competition is reflected in Fig. 1, where the slopes of the lines decrease with increasing woodpecker density. Only one species of woodpecker inhabited the study orchards from which two woodpeckers were reported.

Fig. 2 shows the transformed values of Table I, Column 5, plotted against predator numbers on logarithmic paper. The wide variation is due to intertree variation and the distribution of the larvae within the orchards. In some of the study orchards codling-moth larvae were found to be more plentiful in certain small sections. Larvae frequently aggregate in some sites suitable for cocoons more than in others; this is particularly noticeable where populations are low. The amount of predation depends upon the extent to which these areas are found by woodpeckers. To a lesser extent parasitism of codling moth by the braconid *Ascogaster quadridentata* Wesm. also contributed to variation about the mean; it has been shown (MacLellan, 1958) that woodpeckers take fewer parasitized than non-parasitized larvae and therefore there is less predation by woodpeckers where parasitism is high.

Summary

Analyses showed that woodpeckers were efficient predators of overwintering codling-moth larvae and exhibited intraspecific competition. Woodpeckers frequently reduced the pest population in orchards to a level where other natural control agents were able to prevent the succeeding generation from damaging the fruit to an uneconomical degree. The numbers of woodpeckers, which never exceeded four per location, were estimated in 33 orchards for the years 1954-58. Two methods of study, sight records and observation on signs of feeding activity, showed that these birds live in permanent feeding zones which vary in size according to the food available. In areas that undergo little or no physical change the numbers of woodpeckers may remain steady for several years.

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The author wishes to express his appreciation to Dr. K. E. F. Watt, without whose assistance the statistical analyses would not have been possible, and to Mr. V. C. Henshaw for technical assistance.

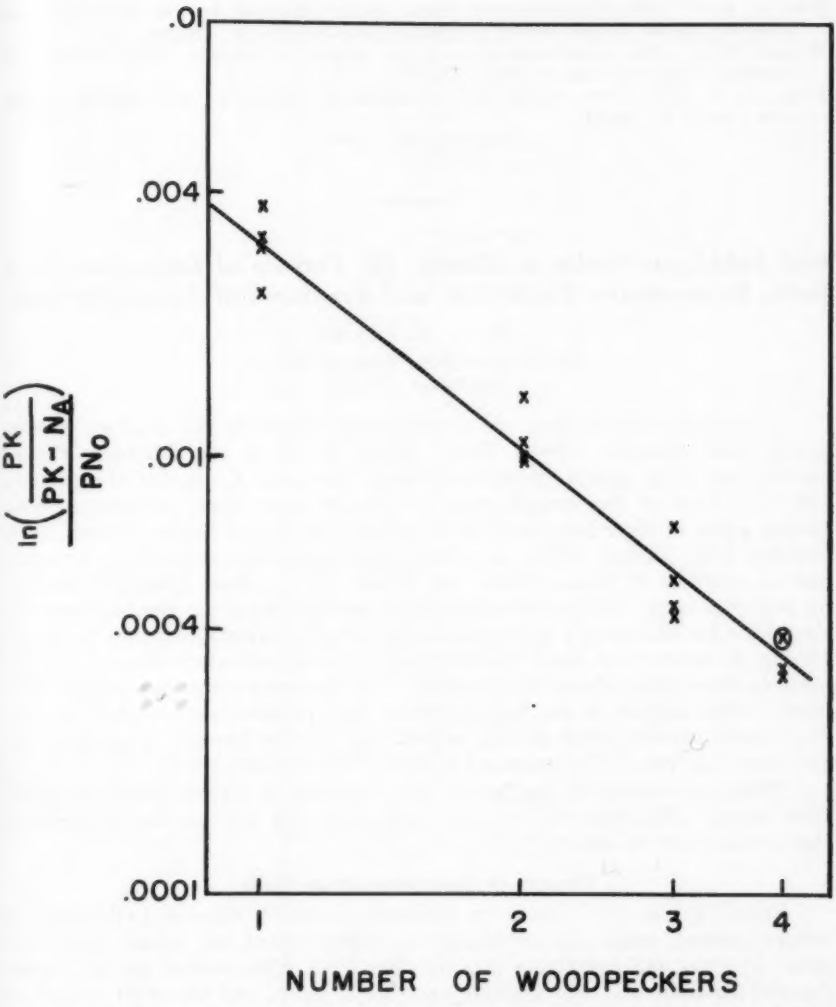

Fig. 2. The relation of the number of woodpeckers to a transformed value of the number of codling moth larvae attacked.

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Gall Aphids on Poplar in Alberta II. Periods of Emergence from Galls, Reproductive Capacities, and Predators of Aphids in Galls[1]

By A. M. HARPER
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Lethbridge, Alberta

In southern Alberta there are several species of aphids that produce galls on poplar trees (Harper, 1959). These aphids are all in the subfamily Eriosomatinae and in the genera *Pemphigus* Hartig, *Thecabius* Koch, and *Mordwilkoja* Del. G. Two of the species are of economic importance, *Pemphigus betae* Doane, a pest of sugar beets in Alberta and parts of United States (Harper, 1957; Maxson, 1916; Parker, 1915), and *Pemphigus populitransversus* Riley, a serious pest of crucifers in Texas (Wene and White, 1953). Both species overwinter on poplar as eggs. In spring the fundatrix emerges from the egg and feeds on the poplar leaf, initiating a gall in which the winged fundatrigeniae are produced. During the summer the fundatrigeniae migrate to the secondary host where they produce the wingless alienicolae; in the fall these in turn produce the winged sexuparae, which migrate to the poplars where they produce the wingless sexuales. The female sexuales, after mating, deposit eggs on the poplars to complete the life cycle (Harper, 1957; Jones and Gillette, 1918; Parker, 1914).

This is an account of the periods of emergence of several species of aphids from poplar galls, their reproductive capacities, and the species of predators that attack them in Alberta.

Periods of Emergence from Galls

From 1953 to 1957 data were obtained within 75 miles of Lethbridge on commencement, peak, and completion of emergence of the aphids from their galls. *P. betae* and *Pemphigus populiglobuli* Fitch were studied on the poplars *Populus balsamifera* L. and *Populus angustifolia* James, and the other species on *Populus sargentii* Dode.

The galls were enclosed in small clip-cages or perforated plastic bags, the latter being used only for the large galls formed by *Pemphigus nortonii* Maxson and *Mordwilkoja vagabunda* (Walsh). The aphids were counted and removed from the cages or bags at weekly intervals. In some galls the exit holes did not open wide enough for the fundatrigeniae to escape, in others the aphids appeared to have become infected by a fungus, and in some instances leaves containing the galls fell prematurely from the trees. The data from such galls were not included in this paper.

Table I indicates that *P. betae* and *P. populiglobuli* emerged from their galls earlier than the other species and completed their emergence earlier. Generally 90 per cent of the emergence of these two species was completed three to four

[1]Contribution from Crop Insect Section. From a thesis submitted in partial fulfilment of the requirements for the Ph.D. degree, Washington State College, 1957.

TABLE I.

Date of emergence of aphids from poplar galls near Lethbridge, Alberta, 1953–1957

Species	Years studied	Number of galls observed	Date of first emergence		Mean date for emergence of		Date of last emergence	
			Mean	Range	50%	90%	Mean	Range
Pemphigus betae	4	174	July 1	June 20–July 7	July 11	July 23	Aug. 7	July 27–Aug. 19
P. populiglobuli	4	189	July 1	June 20–July 7	July 15	July 20	Aug. 10	July 25–Aug. 21
P. populicaulis	4	123	July 7	June 27–July 11	July 24	Sept. 11	Sept. 26	Sept. 15–Oct. 14
P. populitransversus	5	49	July 10	June 27–July 16	Aug. 2	Aug. 23	Sept. 18	Aug. 21–Oct. 11
P. nortonii	3	80	July 5	June 27–July 11	July 13	Aug. 6	Sept. 6	Aug. 18–Sept. 26
P. populiramulorum	2	15	July 7	July 4–July 10	Aug. 1	Aug. 23	Sept. 20	Sept. 5–Oct. 4
Mordwilkoha vagabunda	3	41	July 17	July 11–July 28	July 29	Aug. 5	Aug. 21	Aug. 11–Sept. 5

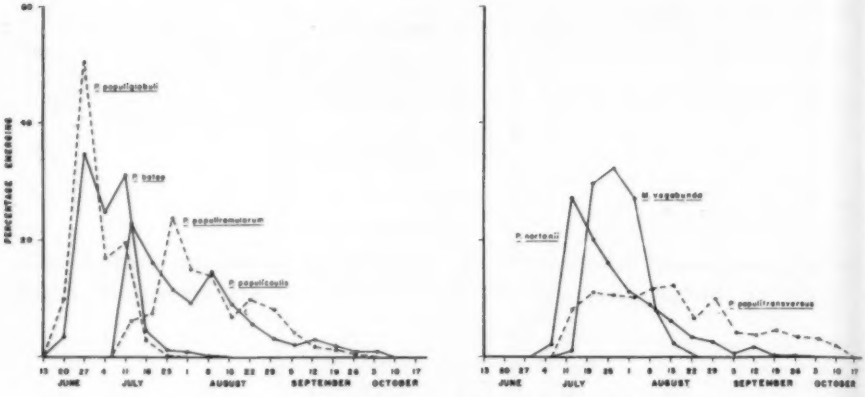

Fig. 1. Percentages of aphids of various species emerging weekly from poplar galls in southern Alberta in 1956.

weeks after the first aphids left the galls. *M. vagabunda* was the last species to start emerging from the galls but generally it completed 90 per cent emergence in approximately three weeks. *P. populicaulis*, *P. populitransversus*, *P. nortonii*, and *P. populiramulorum* generally started to emerge from their galls about one to two weeks later than *P. betae* and *P. populiglobuli* and one to two weeks earlier than *M. vagabunda* but did not complete emergence until fall. In general 90 per cent of the emergence was completed by *P. nortonii* in early August, by *P. populitransversus* and *P. populiramulorum* in late August, and by *P. populicaulis* in early September.

In 1956 *P. betae* and *P. populiglobuli* had high rates of emergence in late June and early July and completed emergence in late July and early August (Fig. 1). Fig. 1 shows also that *P. nortonii*, *P. populitransversus*, *P. populicaulis*, and *P. populiramulorum* emerged mainly during July and August but continued emerging until the leaves fell from the trees in autumn. *M. vagabunda* emerged from early July to mid-August but reached its peak of emergence in late July.

Reproductive Capacities

Table II shows that the number of aphids emerging from galls of *M. vagabunda* averaged more than ten times that of *P. betae* and of *P. populiglobuli*, eight times that of *P. populiramulorum*, three to four times that of *P. populicaulis* and of *P. populitransversus*, and twice that of *P. nortonii*.

Galls of six species were collected in 1955 and 1956 on the day the fundatrigeniae began emerging. Within 24 hours the fundatrigeniae in the galls and the embryos still in the fundatrices were counted. The reproductive potentials were:—

	P. betae	*P. populi-globuli*	*P. populi-caulis*	*P. populi-transversus*	*P. nortonii*	*M. vagabunda*
Mean	164	185	340	428	535	922
Range	87–243	77–319	250–539	168–667	269–775	216–1799

TABLE II.

Number of aphids of various species emerging from poplar galls near Lethbridge, Alberta, 1953–1957.

Species	Years studied	Number of galls observed	Number emerging	
			Range	Mean
Pemphigus betae	4	174	41	2–180
P. populiglobuli	4	189	56	8–174
P. populiramulorum	2	15	74	9–190
P. populicaulis	4	123	123	8–426
P. populitransversus	5	49	192	25–962
P. nortonii	3	80	315	20–812
Mordwilkoja vagabunda	3	41	637	98–2040

By comparing means using Fisher-Behrens' method (Fisher and Yates, 1953, pp. 3-4) it was found that there was a highly significant difference between all means except those of *P. betae* and *P. populiglobuli;* there was no significant difference between the means of these two species.

The reproductive potential follows the same trend as the emergence (Table II), *P. betae* having the lowest emergence and the lowest reproductive potential and *M. vagabunda* the highest. There was a positive correlation of 0.992 between the number of aphids of each species emerging and the reproductive potential.

The embryos in the fundatrices were in various stages of development when examined; thus the reproductive potential might be slightly higher than indicated by these figures. However, because the fundatrices of each species were examined on the day the fundatrigeniae first emerged from the galls there was a similar stage of development used in making the comparisons of reproductive potential.

The number of fundatrigeniae that emerged from the galls of various species did not reach the reproductive potential of the fundatrices. It was expected that the percentage of potential progeny that emerged from the galls of each species would be approximately the same. However, as the reproductive potential of the fundatrices increased the percentage of the potential progeny that emerged also increased. There was a positive correlation of 0.961 between percentage emergence and reproductive potential.

In 1955, mature fundatrigeniae from the galls of six species were dissected and the number of embryos counted. The reproductive potentials were:—

	P. betae	*P. populi-globuli*	*P. populi-caulis*	*P. populi transversus*	*P. nortonii*	*M. vagabunda*
Mean	13.3	17.9	19.6	19.4	27.4	11.1
Range	11–14	17–19	17–24	15–24	25–28	9–13

By comparing means using Duncan's multiple range test it was found that there was a highly significant difference between all means except those of *P. populi-*

caulis and *P. populitransversus;* there was no significant difference between the means of these two species.

When the fundatrigeniae were dissected to determine reproductive potential it was found that all the embryos were nearly fully developed whereas in the fundatrices the embryos were in various stages of development. The fundatrices are wingless and continue feeding in the gall as they produce their young whereas the fundatrigeniae are winged and migrate from the gall before producing their young.

Predators

There are several predators of poplar gall aphids in Alberta. *Anthocoris* sp(p). (Hemiptera, Anthocoridae) mainly attack *P. betae, P. populiglobuli, P. nortonii* and *P. populicaulis.* (This species complex appears to be mainly *A. antevolens* White but some specimens seem to be intermediate between typical *A. antevolens* and *A. musculus* Say, according to N. H. Anderson (in litt.), Entomology Research Institute for Biological Control, Belleville, Ontario.) *Syrphus bigelowi* Curran (Diptera, Syrphidae) and a coccinellid beetle *Scymnus* sp. mainly destroy *P. betae* and *P. populiglobuli. Leucopis pemphigae* Mall. (Diptera, Chamaemyiidae) often attacks *P. populicaulis* and is occasionally predatory on the other gall-forming species.

Larvae of the coccinellid *Adalia bipunctata* (L.) and of the chrysopids *Chrysopa nigricornis* Burm. and *Chrysopa plorabunda californica* Coq. were found in galls of *P. betae.* These species are not important predators, as they were found only in galls that had abnormally large openings.

Ants were suspected of being predators in many galls of *P. betae* and *P. populiglobuli* in which single holes had been cut and in which most of the aphids had apparently been removed.

Discussion

At present only two of the poplar gall aphids studied are pests of crops. However, with the present expansion of irrigated areas in southern Alberta additional crops are being introduced and some may become secondary hosts for other poplar gall aphids.

The emergence period of this group of aphids from galls is the period during which the secondary hosts become infested. This may be particularly important in the control of the sugar-beet root aphid, *P. betae.* To reduce infestation Parker (1915) recommended irrigating fields when the aphids were migrating from poplars to beets. In southern Alberta the aphids generally emerge within a six-week period. It would be difficult to keep fields wet for this length of time, and such a practice might increase the root rot problem in the heavier soil areas. Knowledge of emergence is also important in chemical control. Emergence data indicate that an insecticide incorporated into the soil at the time of seeding must remain toxic for approximately four months to control the aphids and that a foliage spray for control of migrants must either remain toxic for four to six weeks or be applied more than once. *P. populicaulis, P. populitransversus, P. nortonii,* and *P. populiramulorum* have migration periods that are longer than those of *P. betae.* If these aphids become a problem in Alberta, they would be difficult to control because of the long migration period.

P. betae and *P. populiglobuli* are very similar biologically. They inhabit the same hosts, are distributed over similar areas of Alberta, are attacked by many of the same predators, and have almost identical reproductive potentials and dates of emergence. However, they can be separated anatomically and by the galls they produce on the primary host.

Summary

In the years 1953 to 1957 in southern Alberta *Pemphigus betae* Doane and *P. populiglobuli* Fitch commenced to emerge in late June or early July and generally completed 90 per cent of their emergence three to four weeks after the first aphids left the galls. *P. populicaulis* Fitch, *P. populitransversus* Riley, *P. nortonii* Maxson, and *P. populiramulorum* Riley generally started to emerge one to two weeks later than *P. betae* and *P. populiglobuli* and did not complete their emergence until fall. In general 90 per cent of the emergence was completed by *P. nortonii* in early August, by *P. populitransversus* and *P. populiramulorum* in late August, and by *P. populicaulis* in early September. *Mordwilkoja vagabunda* (Walsh) commenced to emerge one to two weeks after *P. populicaulis* but generally completed 90 per cent of its emergence in approximately three weeks.

The number of aphids emerging from galls of *M. vagabunda* averaged more than ten times that of *P. betae* and of *P. populiglobuli*, eight times that of *P. populiramulorum*, three to four times that of *P. populicaulis* and of *P. populitransversus*, and twice that of *P. nortonii*.

Fundatrices of *P. betae* had the lowest mean reproductive potential (164) and *M. vagabunda* the highest (922). The mean reproductive potentials of the fundatrices of *P. populiglobuli*, *P. populicaulis*, *P. populitransversus*, and *P. nortonii* were 185, 340, 428, and 535, respectively. The fundatrigeniae of *M. vagabunda* had the lowest mean reproductive potential (11.1) and *P. nortonii* the highest (27.4). The reproductive potentials of the fundatrigeniae of *P. betae*, *P. populiglobuli*, *P. populitransversus* and *P. populicaulis* were 13.3, 17.9, 19.4, and 19.6, respectively.

As the reproductive potential of the fundatrices increased there was an increase in the number of fundatrigeniae leaving the galls and also in the percentage of potential progeny that emerged.

The most important predators of gall aphids on poplars in southern Alberta were the anthocorid *Anthocoris antevolens* White, the syrphid *Syrphus bigelowi* Curran, the fly *Leucopis pemphigae* Mall., and the coccinellid *Scymnus* sp.

Acknowledgments

The writer wishes to thank Mr. A. C. Maxson, Longmont, Colorado, for checking the identification of the aphids, Mrs. Jean B. Adams, Canada Agriculture Research Station, Fredericton, N.B., and officers of the Canada Agriculture Research Station, Lethbridge, Alberta, for criticisms and suggestions in the preparation of the manuscript, and Mr. T. P. Story, Technician, for his valuable assistance.

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New Canadian Black Flies (Diptera : Simuliidae) III

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The following descriptions are based on material collected during a field trip to the east coast of Vancouver Island, British Columbia in June 1955. Most of the streams concerned are in the vicinity of Qualicum Bay, a summer resort midway between the cities of Nanaimo and Courtenay. Lying in the lee of the mountainous interior of the island, this narrow strip of coastal forest has a climate somewhat drier than is normal for the region as a whole. The annual precipitation is less than 50 inches and there is a pronounced dry period in July and August. The short coastal rivers are in spate in the fall and winter months when the heaviest rainfall occurs. They are fast and shallow with clean beds of gravel or small boulders. Because of limited water storage in the hinterland, flash-flooding is frequent after rain storms. Vegetation of the forest floor is lush and the courses of the smaller streams are often concealed by dense thickets of salmonberry (*Rubus spectabilis* Pursh.), thimbleberry (*Rubus parviflorus* Nutt.) and other shrubs that overhang the banks. During the spring and early summer, conditions appear to be very favourable for the propagation of black flies. In late May, one of the *Prosimulium* species described herein was already past its peak of emergence and the occurrence of even earlier species seems probable.

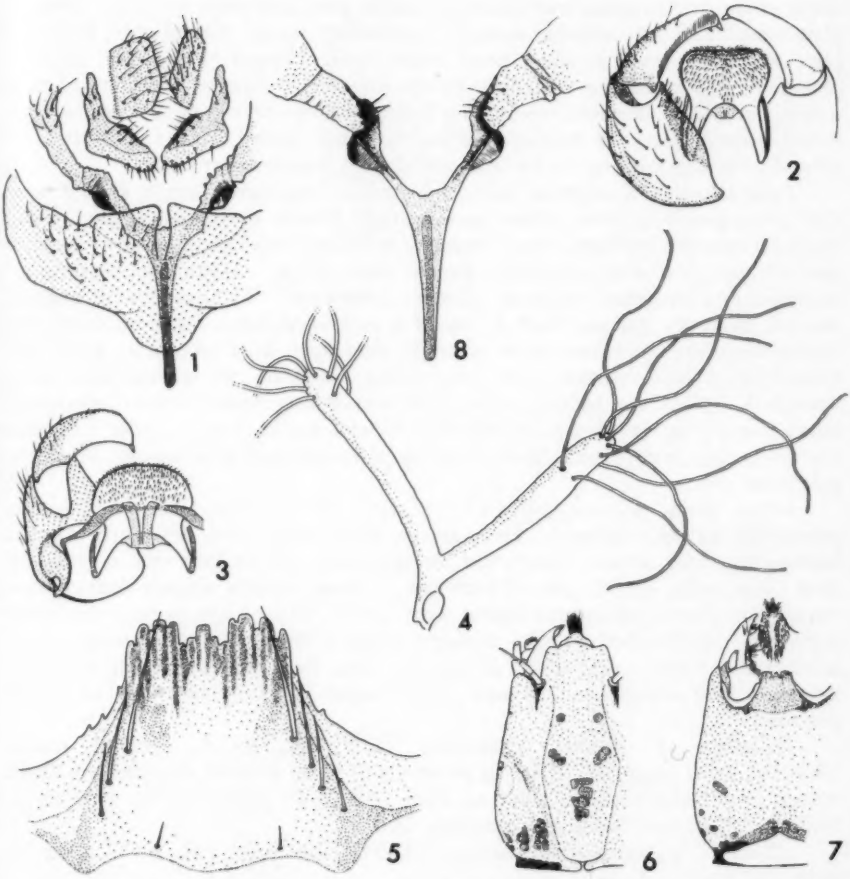
Twinnia biclavata n.sp.

Greyish black species. Occiput with bulla at posterior margin of eye. Male holoptic. Vestiture of female pale yellow; frons broad; tarsal claw simple. Length of body 2.5 mm., of wing 3.5 mm.

Female (Fig. 1).—Head black, dull grey-pollinose. Frons above nearly two-fifths and below nearly one-fifth as wide as head, with sparse decumbent pale yellow pile and a few suberect dark hairs laterally and below. Clypeus one and a half times as wide as lower frons, pale yellow-pilose with a few black hairs below. Occiput with long pale yellow pile; hairs of fringe well-developed, black; near middle of posterior margin of eye, a shining black subtriangular slightly swollen area. Antenna and palpus black, the former 9-segmented; hairs dark with pale reflections. Blades of mandible and maxilla serrate.

Thorax black; scutellum, pleural incisures and knob of haltere dark brown; pollen dull grey; hairs pale yellow, somewhat matted on dorsum. Wing clear; hairs of stem vein pale yellow, sometimes dark basally; other hairs black. Legs dark brown to black; hairs pale yellow except those on fore- and mid-tarsi and on last four segments of hind tarsi which are black. Hind metatarsus about five and a half times as long as broad. Claw simple, moderately curved.

Abdomen black, dull grey-pollinose; hairs pale yellow, sometimes the dorsum with brown hairs and with some long dark hairs laterally and apically on last one or two segments. Second to fifth tergites noticeably reduced. Paraproct narrow, strap-like above, abruptly expanded oblong-ovate below cercus, upper half of expanded portion more heavily pigmented and with an incurved flange. Cercus twice as broad as long, apical margin weakly convex. Genital fork short and stout, stem gradually widening posteriorly, arms broad on basal third and abruptly expanded near apex, the expanded portion heavily pigmented on the rounded outer side, pale on the serrated inner margin, a thickened ridge running



Figs. 1-7. *Twinnia biclavata* n.sp. 1. Female; terminalia, ventral. Allotype. 2. Male; hypopygium, ventral. 3. The same, dorsal. 4. Pupa; right respiratory organ, lateral. Filaments of dorsal club partly omitted. 5. Larva; submentum. 6. Larva; head, dorsal. 7. The same, ventral.

Fig. 8. *Twinnia nova* (D. & S.). Female; genital fork. Paratype. Two Medicine Lake, Mont.

lengthwise through it. Anterior gonapophyses shorter than their width at base; inner margins approximated; tips rounded.

Male (Figs. 2, 3).—Entirely dull greyish- or brownish-black, including the hairs on body, wings and legs. Sometimes the long erect pile on posterior parts of thoracic dorsum paler, more brownish. Occipital bulla situated at lower third of eye margin. Antenna 9-segmented, second and third segments as long as or slightly longer than wide, others except ninth shorter than wide, ninth nearly twice as long as wide. Haltere black. Wing clear; anterior veins grey.

Coxite in ventral view about two thirds as broad as long; laterally on basal margin with a strong curved apodeme delimited at its base by a suture. Style about four fifths as long as coxite, evenly curved; apex broadly rounded with a

single strong tooth; sometimes a second smaller preapical tooth present. Ventral plate broad and flat, without strongly protruding lip on ventral side; body of plate expanded towards apex; basal arms slightly longer than body, slightly divergent, almost straight. Median sclerite furcate. Paramere consisting of two narrow strap-like elements, one arising from apodome of coxite and passing between ventral plate and median sclerite, the other arising from end of arm of ventral plate and curving backward parallel with arm to latter's base.

Pupa (Fig. 4).—Length of body 3.5 mm., of respiratory organ 1.5-2.0 mm. Latter composed of two (dorsal and ventral) widely divergent inflated club-shaped trunks arising from a short common stalk and each bearing 8 fine filaments near its tip; filaments noticeably longer than trunk. Abdominal segment 3 completely sclerotized, without pleural membrane. Tergites finely rugose, towards posterior margins with a row of 6 to 8 weak hairs, those on third and fourth segments sometimes more strongly developed hook-like, but, if so, not conspicuous. Fifth sternite with four strong hooks in two groups near mid-ventral line, sixth and seventh each with four strong hooks, widely separated, outer ones lying in pleural membrane. Caudal hooks long, slender, sinuous. Cocoon a thin transparent sheath covering abdomen only and having, in situ, a gelatinous sheen.

Larva (Figs. 5-7).—Length 6.5-7.5 mm. Mouth fans absent. Abdomen posteriorly strongly bulbous. Head brown with conspicuous dark brown spots. Submentum with a short blunt trifid median tooth and on each side a group of four blunt teeth, central pair of each lateral group usually slightly longer than others; lateral margins serrate; lateral setae three. Gular cleft absent. Antennal segments 1 and 2 subequal, pale; segments 3 and 4 black. Mandible with twelve blunt apical teeth, apical seven of uniform size, basal five decreasing to blunt bristles. Anal sclerite "Y"-shaped. Anal hooks in 60-70 rows, 11-13 hooks per row.

Holotype, ♂, Bowser, Vancouver Island, B.C., G. E. Shewell, reared 3.VI.1955 from pupa coll. 31.V. on underside of stone in small sluggish woodland stream near railroad track; adult on slide 5902-05 F; pupa on slide 5902-10 A. No. 6925, Canadian National Collection, Ottawa.

Allotype, ♀, Same data; reared 5.VI.1955 from pupa coll. 4.VI.; adult on slide 5902-06.

Paratypes, 2 ♂♂, 14 ♀♀, individually reared 30.V.-13.VI.1955, 15 pupae and pupal skins and 14 larvae, all from same stream.

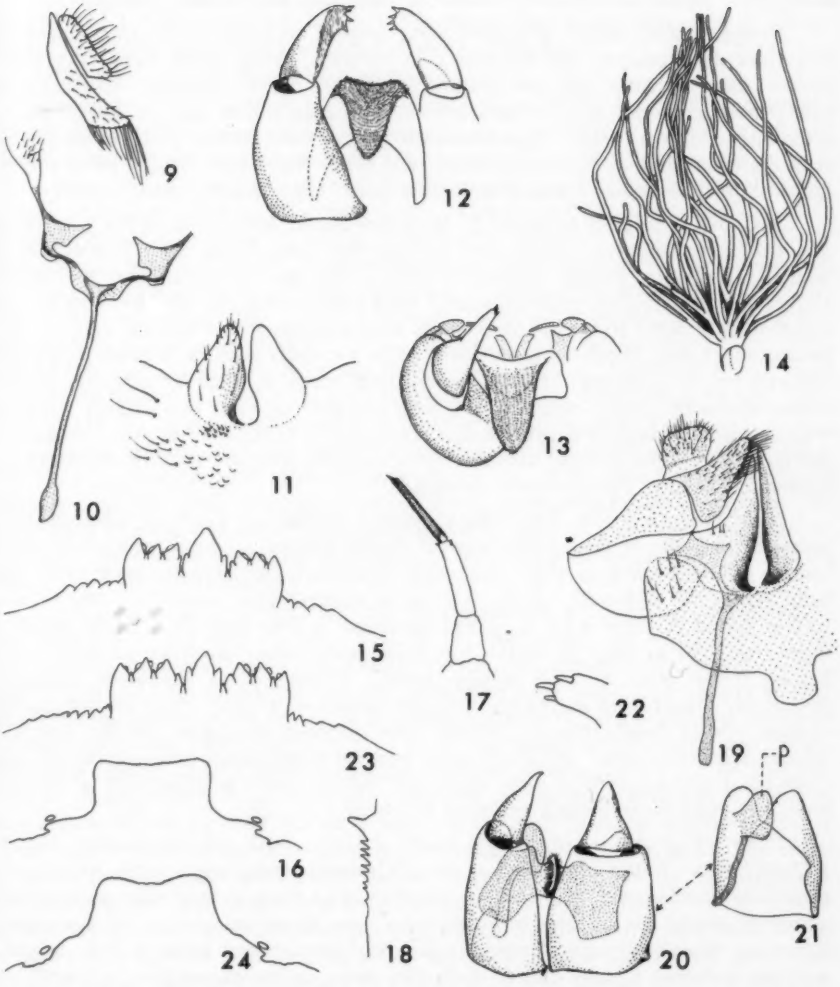
Comments.—This species is very close to *T. nova* (D. & S.) but is somewhat smaller with shorter more robust legs. The genital fork of *nova* (Fig. 8) is differently shaped and there is an isolated group of long hairs at the junction of its arm with the ninth tergite. In *biclavata* n.sp. these hairs are absent or greatly reduced in size.

Prosimulium caudatum n.sp.

Prosimulium dicum Dyar and Shannon, 1927, Proc. U.S. Natl. Mus. 69, Art 10. p. 7. *In part.*

Dark brown to black. Male holoptic, with mostly black pile. Female with legs mostly pale brownish-yellow; tarsal claws simple; paraproct with a conspicuous decumbent brush of long apical hairs. Length of body 3.0-3.5 mm., of wing 3.3-3.8 mm.

Female (Figs. 9-11).—Head black, thinly dull grey-pollinose. Frons at vertex two-fifths and at antennae less than one fourth of width of head. Clypeus below as broad as high, somewhat narrowed above. Pile pale yellow, decumbent, with the usual sparse fringe of suberect black hairs bordering eyes on frons,



Figs. 9-18. *Prosimulium caudatum* n.sp. 9. Female; left paraproct and cercus. 10. Female; genital fork. 11. Female; anterior gonapophyses. 12. Male; hypopygium, ventral. 13. The same, terminal view. 14. Pupa; right respiratory organ, lateral. 15. Larva; teeth of submentum. 16. Larva; gular cleft. 17. Larva; antenna. 18. Larva; subapical ridge of mandible. Adults and larvae from Nile Creek. Pupa from Honeymoon Bay.

Figs. 19-24. *Prosimulium dicum* D. & S. 19. Female; terminalia. Type. Hoodsport, Wash. 20. Male; hypopygium, ventral. Lectotype of *P. exigens* D. & S. Moscow, Idaho. 21. The same, right coxite, dorsal view, showing expanded apical portion of paramere (p). 22. The same, tip of right style, drawn from a cotype. 23. Larva; teeth of submentum. 24. Larva; gular cleft. (Larva from Nile Creek).

clypeus and occiput. Antenna 11-segmented, black, with pale pubescence and sparse black hairs. Palpus black with black hairs; third and fifth segments equal in length. Mouthparts brown; blades of mandible and maxilla serrate.

Thorax black, thinly grey-pollinose; pleural incisures, root of wing and scutellum deep brown; pile entirely pale yellow. Wing clear; veins very pale yellow; hairs of stem vein pale yellow, of others black. Haltere brown; hairs pale yellow. Coxae black or dark brown with pale yellow hairs. Trochanters, femora, and most of tibiae light brownish-yellow with mostly pale yellow hairs. Apical sixth or less of tibiae and entire tarsi black with black hairs. Hind metatarsus slightly over five times as long as broad. Claw simple, evenly curved.

Abdominal tergites subshining, brownish-black; hairs pale yellow; seventh and following segments with some conspicuous long black hairs laterally and below. Paraproct greatly produced downward, not conspicuously narrowed above, almost straight, without strong backward curvature beneath cercus, its apical margin with fringe of black hairs almost as long as width of cercus. In pinned specimens, these hairs normally form a conspicuous decumbent brush at extreme tip of abdomen. Cercus nearly four times as wide as long; its lower corner distinctly acute. Genital fork long and slender, each arm slightly sinuous with an apical triangular expansion that is notched at base on inner side. Anterior gonapophyses twice as long as wide; inner margins strongly sinuous, moderately pigmented basally; tips narrowly rounded.

Male (Figs. 12, 13).—Dull black, greyish-pollinose. Hairs of anterior and posterior margins of mesonotum and of dorsal surfaces of hind femur and tibia usually light brownish or yellowish; other hairs, including those of stem vein and basal fringe of abdomen, black. Coxite in ventral view somewhat more than half as broad as long, with a curved apodeme at base laterally. Style slightly more than half as long as coxite, the broad apex rather abruptly incurved and bearing from two to four strong teeth. Ventral plate shallowly concave posteriorly; ventral lip extremely long, in caudal view over twice as long as its median width; basal arms in ventral view slightly divergent, evenly curved. Median sclerite furcate. Paramere with well-developed narrow triangular sclerite from basal arm of ventral plate and small subtriangular sclerite with strap-like inner extension from behind apodeme of coxite.

Pupa (Fig. 14).—Length of body 4,5-5.0 mm., of respiratory organ 1.25-1.75 mm. Latter composed of 20-23 filaments arising singly or in pairs from extremely short trunks, branching in most cases so close to base that presence of common trunks giving rise to more than two filaments cannot be discerned. Filaments often noticeably sinuous or abruptly bent several times in their length, together forming a loose cluster with tips more or less convergent. Fourth to seventh abdominal sternites each with four strong hooks, those on fourth in two close-set pairs. Cocoon thick, covering entire body.

Larva (Figs. 15-18).—Length 7.5-8.0 mm. Head light brown, somewhat darker posteriorly. Pattern of head inconspicuous; median row only of frontoclypeal spots differentiated as a narrow darker line. Median tooth of submentum three-fourths as broad as each lateral group, its apex noticeably protruding beyond line of lateral teeth but its lateral tines small and not reaching this line. Outer teeth not exceeding intermediate pair in length. Gular cleft rectangular, twice as broad as deep; inner corners almost square, not noticeably rounded. Subapical mandibular ridge with 9-11 upright teeth which are longer on apical half. First antennal segment over half as long as second. Anal sclerite with

median area and anterior arms broadly pigmented. Anal hooks in 82-90 rows, 13-15 hooks per row.

Holotype, ♀, Nile Creek, Qualicum, Vancouver Island, B.C., G. E. Shewell; reared 13.VI. from pupa coll. 12.VI.1955; adult on pin, pupa in glycerin in microvial. No. 6926, Canadian National Collection, Ottawa.

Allotype, ♂, same data. Reared 14.VI.1955.

Paratypes, 27 ♂♂, 13 ♀♀, 70 pupae and pupal skins, 30 larvae, topotypical, 31.V.-12.VI.1955; adults individually reared. 3 ♂♂, 14 ♀♀, many pupae and pupal skins, 1 larva, Honeymoon Bay, Cowichan Lake, Vancouver Island, B.C., 6.VI.1955, G. E. Shewell; adults individually reared. 1 ♂, 1 ♀, many pupae and pupal skins, 40 larvae, Haslam Creek, Cassidy, Vancouver Island, B.C., 2-14.VI.1955, G. E. Shewell; adults individually reared. 1 ♂, Ivy Green Provincial Park, near Ladysmith, Vancouver Island, B.C., 2.VI.1955, G. E. Shewell. 2 ♀♀, Big Qualicum River at Horne Lake, Vancouver Island, B.C., 1.VI.1955, G. E. Shewell; biting man. 1 ♀, Qualicum, Vancouver Island, B.C., 6.VI.1955, G. E. Shewell; on car window. 1 ♀, Cameron Lake, Vancouver Island, B.C., 4.VI.1955, J. R. McGillis; hovering round man. 7 ♀♀, Cameron Lake, Vancouver Island, B.C., 29.VI.1933, J. McDunnough. 1 ♀, Hoodsport, Wash., May 3, 1924, H. G. Dyar; paratype of *Prosimulium dicum* D. & S.

Comments.–P. caudatum breeds in fast clear shallow woodland streams often in close association with *Prosimulium dicum* D. & S., the pupae clustering together on the upper surfaces of rocks barely submerged beneath ripples. *P. caudatum* emerges a week or two earlier than *dicum* and is perhaps restricted to the coast for I have found no specimens of it in Hearle's large collections from the interior of the mainland.

The type slide of *dicum* (Fig. 19) shows that the genitalia are essentially as illustrated by Dyar and Shannon (1927). In particular, the paraproct has the tip curving backward under the cercus in the normal way and clothed on the lower margin with numerous but not unusually long hairs. According to my material, this species is the female of *Prosimulium exigens* D. & S. It is a common western species of which the pupa has a short respiratory tuft of about 80-100 fine filaments arising mostly singly or in short-petiolate pairs from a knob-like base. There has apparently been confusion regarding the identity of *dicum* because of the colour of the hairs of the stem vein. Dyar and Shannon described this as black-pilose in *dicum* and pale-pilose in *Prosimulium dicentum* D. & S. The latter was said to differ from *dicum* only in this character and in having the paraproct "more rounded" and "less coarsely hairy ventrally". As a result, most western specimens agreeing with the description of *dicum* except for the pale hairs of the stem vein have been identified as *dicentum* and because pale-haired specimens seem to predominate in the interior of British Columbia, Hearle (1932) concluded that *dicum* was a rare species.

A series of individually reared females from Vancouver Island shows that this character is not constant in *P. dicum*. Of 45 specimens reared from three different streams, 28 have the stem-vein black-pilose, 11 pale-pilose, and 6 have both black and pale hairs. I therefore propose that this western species having the male genital characters of *P. exigens* as shown by the type slide (Figs. 20, 21) and having a multi-branched pupal respiratory organ as described above, should be known as *Prosimulium dicum* D. & S., 1927 (= *Prosimulium exigens* D. & S. 1927, new synonymy). *P. dicum* and *P. dicentum* have until now been considered distinct species and the slight genitalic differences between them noted by Dyar and Shannon tend to support this view. However, Peterson

(1955) has published the synonymy of *exigens* and *dicentum* so that the possibility of all three names referring to the same species should not be overlooked.

***Prosimulium formosum* n.sp.**

Brownish-black; thoracic pile bright orange-yellow. Legs of female orange-yellow. Male holoptic; legs light yellowish-brown basally. Length of body 3.0-4.0 mm., of wing 3.5-4.6 mm.

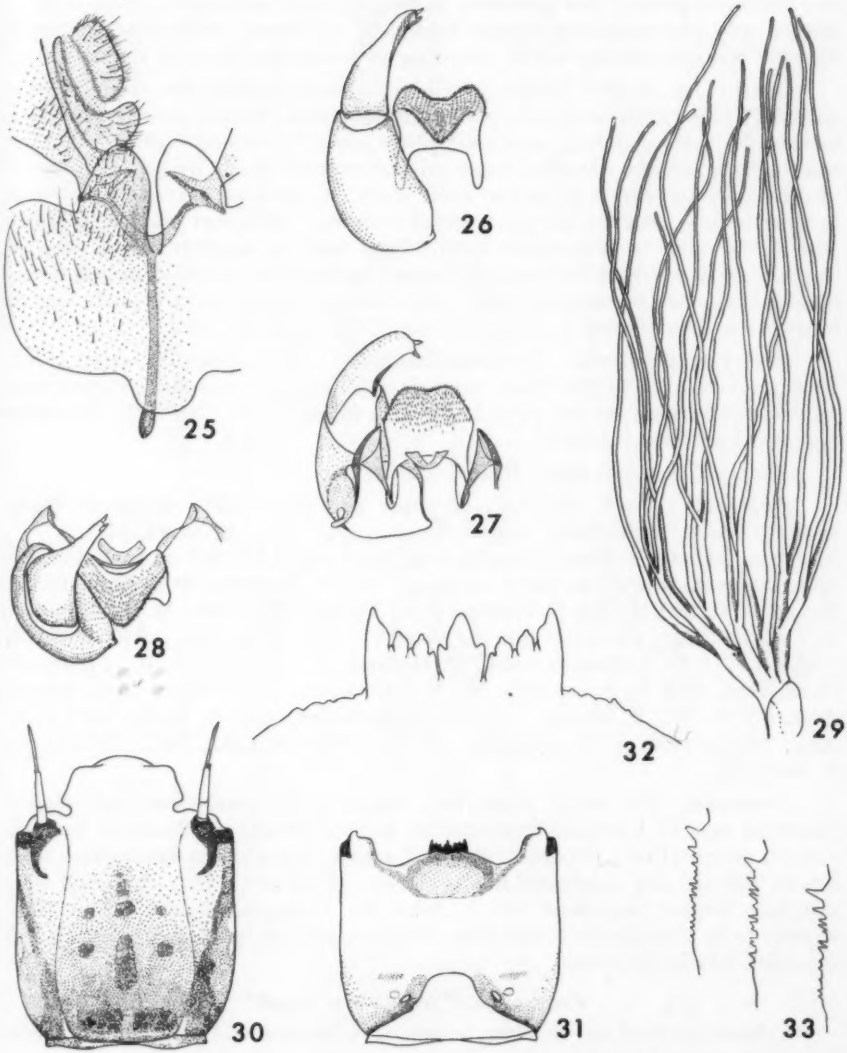
Female (Fig. 25).—Head black, thinly dark grey-pollinose. Frons at vertex two-fifths as wide as head, strongly narrowed below, thickly clothed with decumbent yellow hairs, laterally with a few black hairs. Clypeus below as broad as high, somewhat narrowed above; hairs yellow, with a few black ones laterally and below. Occiput thickly yellow-pilose; black hairs of the occipital fringe long and reaching almost to ventral margin of eye. Antenna 11-segmented, black; first and second segments often light brown; pubescence pale; hairs black. Palpus black; fifth segment equal to or slightly longer than third; hairs black. Mouthparts brownish; blades of mandible and maxilla serrate.

Thorax black, sparsely greyish-pollinose; humerus, root of wing, and scutellum brownish; pile, especially the long erect hairs posteriorly on mesonotum and scutellum, vivid orange-yellow. Wing clear; veins light brown; hairs of stem vein orange-yellow, of other veins black. Haltere brown with pale yellow hairs. Legs rather long and slender. Coxae brown with orange-yellow hairs. Femora entirely and tibiae except apical sixth, orange-yellow, darkening with age to tawny; hairs concolorous. Apices of tibiae and entire tarsi black with black hairs. Hind metatarsus six times as long as wide. Claw simple, moderately and evenly curved.

Abdomen dark brown to black; tergites subshining; hairs orange-yellow. Paraproct small, "L"-shaped, narrow and parallel-sided above, abruptly widened below but not strongly produced behind cercus, evenly clothed with short hairs. Cercus twice as wide as long. Genital fork long and slender; each arm much like *fulvithorax* n.sp., but inner projection longer than outer. Anterior gonapophyses not quite twice as long as wide, inner margins strongly sinuous, outer margins convex, tips rounded.

Male (Figs. 26-28).—Dull greyish-black. Brownish areas much less conspicuous than in female. Hairs of lower occiput pale yellow, of rest of head black. Antenna black, third segment enlarged, slightly longer than wide, wider than remaining flagellar segments. Mouthparts, including palpi, black. Hairs of mesonotum light orange-yellow, deeper orange posteriorly and on scutellum. Haltere dark brown; hairs black. Coxae and trochanters dark brown to black; hairs pale yellow. Femora light yellowish-brown with mostly pale yellow hairs, towards apices darkening to black with concolorous hairs. Tibiae and tarsi black with black hairs; sometimes fore- and mid-tibiae a little paler medially. Hind metatarsus four times as long as wide.

Abdomen uniformly black with subshining grey pollinosity. Hairs of basal fringe black at base becoming pale yellow on apical half or less; other hairs yellow. Coxite in ventral view about two thirds as broad as long, with a strong curved laterobasal apodeme. Style almost as long as coxite, evenly curved to broadly rounded apex bearing two strong rather widely separated teeth. Ventral plate with broad shallow depression on posterior surface; ventral lip well developed; basal arms slightly divergent, almost straight. Median sclerite furcate; arms strongly divergent. Paramere consisting of slender lamellae arising from



Figs. 25-33. *Prosimulium formosum* n.sp. 25. Female; terminalia, ventral. 26. Male; hypopygium, ventral. 27. The same, dorsal. 28. The same, terminal. 29 Pupa; right respiratory organ, lateral. 30. Larva; head capsule, dorsal. 31. The same, ventral. 32. Larva; teeth of submentum. 33. Larva; subapical ridge of mandible; examples from three individuals.

apodeme of coxite and from arm of ventral plate becoming more or less fused towards posterior corner of latter.

Pupa (Fig. 29).—Length of body 5.0 mm., of respiratory organ 2.75 mm. Latter composed of 16 uniformly slender filaments in a moderately compact clump arising from three short trunks; ventral and lateral trunks each with four filaments; dorsal trunk with two branches of three, and between them a branch of

two filaments; primary and secondary branchings very uniform and close to base, usually only one occurring beyond basal fifth of organ. Abdominal armature normal. Cocoon thickly-woven, covering abdomen and most of thorax.

Larva (Figs. 30-33).—Length 7.5-8.5 mm. Head light brown; frontoclypeus anteriorly pale yellowish-brown, posteriorly around head-spots darker; spots dark brown, the pattern diffuse; epicranial plates around eye-spots and on posterior margin dark brown. Median tooth of submentum much longer than intermediate pairs and almost as long as outer teeth. Gular cleft shallow, over twice as wide as deep, anterior margin rounded-truncate. Subapical mandibular ridge with 11-15 rather widely-spaced teeth. Basal antennal segment half as long as second. Anal sclerite with broad pigmented median area; a row of minute spines in membrane behind anterior arms; latter narrow basally, evenly expanding to broad apex. Anal hooks in about 70 rows, 13-15 hooks per row.

Holotype, ♀, Bowser, Vancouver Island, B.C., G. E. Shewell; reared 16.VI. from pupa coll. 13.VI.1955 from stone in small sluggish woodland stream near railroad track; adult on pin, pupa in glycerin in microvial. No. 6927, Canadian National Collection, Ottawa.

Allotype, ♂, same data. Reared 18.VI.1955.

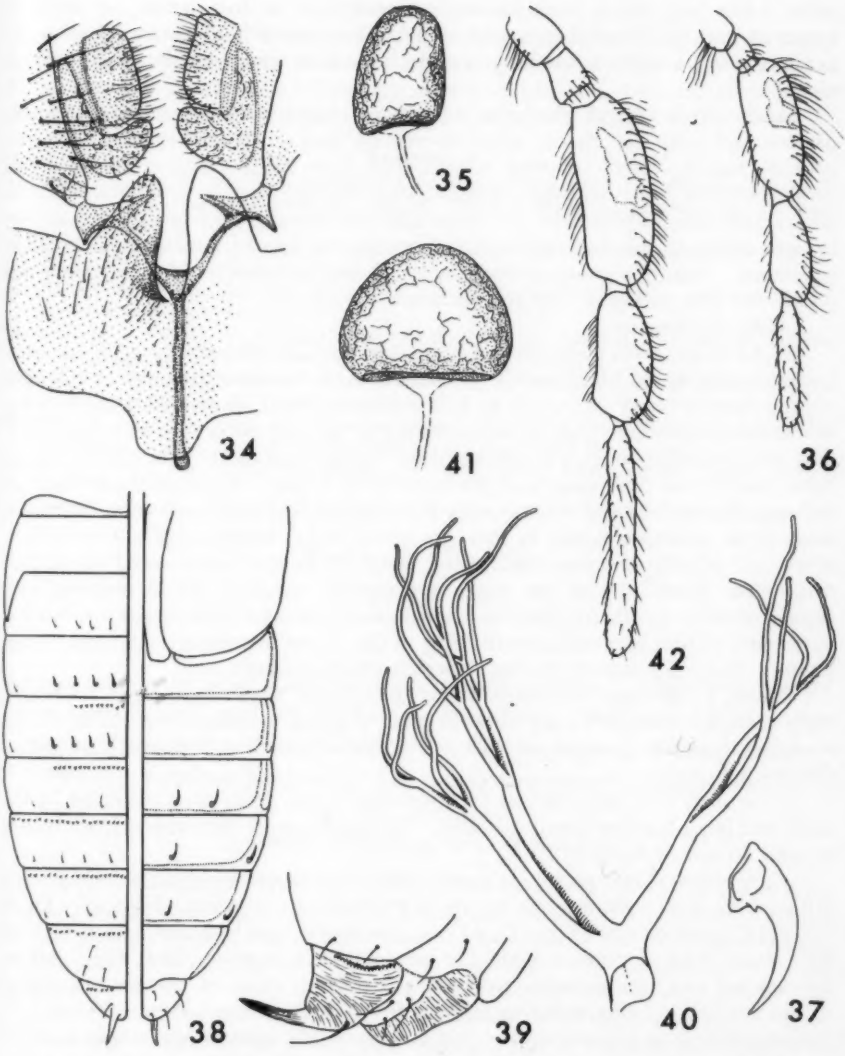
Paratypes, 17 ♂♂, 21 ♀♀, 12 pupae and pupal skins, 40 larvae, topotypical, adults individually reared from pupae coll. 11-13.VI.1955. 1 ♀, Nanaimo, B.C., G. E. Shewell; reared from pupa coll. 2.VI.1955 on stone in small sluggish stream flowing in damp meadow. 3 ♀♀, Foghorn Mtn., Birch Island, B.C., 5500 ft, 17.VII.1928, E. Hearle. 1 ♀, Terrace, B.C., Mrs. M. E. Hippisley, 1-7 April 1933. 15 ♀♀, Mt. Revelstoke Nat'l. Park, B.C., 5400-6300 ft, 3-17.VII.1952, G. J. Spencer and G. P. Holland. 1 ♀, Squamish, B.C., Diamond Head Trail, 3200 ft, 3.Aug.1953, W. R. M. Mason. 1 ♀, Signal Mtn., Jasper, Alta., 8.VIII.1932, E. Hearle. 1 ♀, Tonquin Valley, 6500 ft, Jasper Nat'l Park, Alta., 18.Aug.1932, J. D. Gregson. 2 ♀♀, Watson Lake, Y.T., 28.VI.1949, P. Morrison.

Comments.—The pupal respiratory organ of *P. formosum* n.sp. closely resembles that of European *Prosimulium hirtipes* (Fries) as illustrated by Puri (1925), Smart (1944), Davies (1957) and others, and a direct comparison with British material has confirmed this similarity. Rubtsov (1956) described *Prosimulium hirtipes luganicum* var. n. from the Leningrad district. This form appears to be structurally rather close to *formosum* but has dull golden pile and brownish legs in the female.

Prosimulium fulvithorax n.sp.

Yellow; the head and abdomen brown. Tarsal claw with minute basal tooth. Length of body 2.5-3.0 mm., of wing 3.7-4.0 mm.

Female (Figs. 34-37).—Head dark brown. Frons at vertex two-fifths as wide as head, strongly narrowed below, dull grey-pollinose, with sparse decumbent yellow hairs and laterally a few longer black hairs. Clypeus below as broad as long, somewhat broader than lower frons, with sparse yellow hairs interspersed laterally and below with a few longer black hairs. Occiput dull grey-pollinose, with moderately dense decumbent yellow pile and outstanding fringe of long black hairs extending full length of posterior margin of eye. Antenna 11-segmented, uniformly dark brown with black hairs. Palpus dark brown with black hairs, fifth segment equal to or shorter than third. Blades of mandible and maxilla serrate.



Figs. 34-40. *Prosimulium fulvithorax* n.sp. 34. Female; terminalia, ventral. 35. Female; spermatheca. 36. Female; maxillary palpus. 37. Female; tarsal claw. 38. Pupa; abdominal armature; dorsal, left; ventral, right. 39. Pupa; tip of abdomen, lateral. 40. Pupa; right respiratory organ, lateral.

Figs. 41, 42. *Prosimulium fulvum* Coq. 41. Female; spermatheca. 42. Female; maxillary palpus.

Thorax light brownish-yellow; upper pleural area and postscutellum brown; hairs entirely yellow. Wing clear; stem vein pale brown, hairs rather sparse, mixed yellow and black; other veins greyish with black hairs. Haltere light brown; base of knob darker; hairs pale yellow. Legs uniformly pale yellow with concolorous hairs; apices of tibiae and entire tarsi light brown with black

hairs; a few long black hairs also on posterior apex of fore femur, on anterior apices of mid- and hind femora and on dorsal surface of hind tibia. Hind metatarsus five and a half times as long as wide; claw with an extremely small subbasal tooth.

Abdomen brown; tergites subshining; hairs entirely yellow. Paraproct small, narrow and strap-like above, abruptly curved backwards and slightly upwards beneath cercus, evenly clothed with rather short hairs. Cercus subquadrate, about twice as broad as long. Genital fork slender; each arm slightly sinuous with a long slender projection on either side towards apex, the projections almost at right angles to the arm and together forming the base of a subtriangular apical expansion. Anterior gonapophyses long and slender, twice as long as their basal width, the tips rounded. Spermatheca ovate.

Male.—Unknown.

Pupa (Figs. 38-40).—Length of body 4.0 mm., of respiratory organ 2.0 mm. Latter consisting of 14-15, rarely 16, filaments on three long trunks as follows: a single ventral trunk giving rise to 4 filaments, and two subparallel dorsal trunks, the inner one producing six to seven, rarely 8, and the outer one four filaments. The first branching occurs at one third to one half and the next at two thirds to three fourths the total length of the respiratory organ. Abdominal armature as follows: first and second tergites with hairs only, third and fourth each with the usual eight posterior hooks in two groups of four, fourth tergite also with a short row of minute spines anteriorly. Row of anterior spines on fifth tergite incomplete laterally, that on ninth incomplete mesally. Third, fourth, and eighth sternites unarmed; fifth to seventh with the usual four posterior hooks, outer ones of the sixth and seventh lying in the pleural membrane. Caudal hooks strong. Cocoon a loosely-woven sleeve covering abdomen only.

Type, ♀, Bowser, Vancouver Island, B.C., G. E. Shewell; emerged 7.VI.1955 from pupa collected 4.VI. on stone in small sluggish woodland stream near railroad track; pupa mounted on slide. No. 6928, Canadian National Collection, Ottawa.

Paratypes, 1 ♀, same data as type; emerged 2.VI. from pupa collected 30.V.; adult and pupa both mounted on slides. About 40 pupal skins taken from stones in same stream 30.V-11.VI.1955.

Comments.—This species is closely allied to *Prosimulium fulvum* (Coq.) but differs from it in the much shorter apical segment of the palpus (Figs. 36, 42), in the ovoid spermatheca (Figs. 35, 41), in the sparse, partly black hairing of the stem vein which in *fulvum* is thickly covered with orange-yellow hairs, and in the number and arrangement of the pupal filaments, those of *fulvum*, according to Stone (1952), being indistinguishable from *Prosimulium hirtipes* (Fries). *P. fulvithorax* n.sp. is a much smaller, less conspicuously orange-yellow species with the anterior wing veins greyish rather than yellow.

Summary

Adults and early stages of four new black flies, *Twinnia biclavata*, *Prosimulium caudatum*, *Prosimulium formosum* and *Prosimulium fulvithorax* are described from material collected by the author on the east coast of Vancouver Island, B.C. The climate and topography of the area are briefly described. Under the description of *P. caudatum*, the identities of three species described by Dyar & Shannon, *Prosimulium dicum*, *Prosimulium dicentum* and *Prosimulium exigens* are discussed with reference to the types. The use of the name *Prosimulium dicum* D. & S., 1927 (= *Prosimulium exigens* D. & S., 1927, new synonymy) is proposed.

Acknowledgments

For permission to examine and make drawings of Dyar and Shannon's types, I am grateful to Dr. Alan Stone, United States National Museum, Washington, D.C. Dr. Lewis Davies, Entomology Research Institute, Ottawa, very kindly supplied material of *Prosimulium hirtipes* (Fries) from Britain.

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Status in Ontario of *Collyria calcitrator* (Grav.) (Hymenoptera: Ichneumonidae) and of *Pediobius beneficus* (Gahan) (Hymenoptera: Eulophidae) as Parasites of the European Wheat Stem Sawfly, *Cephus pygmaeus* (L.) (Hymenoptera: Cephidae)[1]

By R. W. SMITH
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Collyria calcitrator (Grav.) is an important parasite of the wheat stem sawflies *Cephus pygmaeus* (L.) and *C.* (*Trachelus*) *tabidus* (F.) in Europe (Salt, 1931). It was imported from England and released against the wheat stem sawfly, *Cephus cinctus* Nort., in the Prairie Provinces, especially Saskatchewan, from 1930 to 1939. One of its usual hosts, the European wheat stem sawfly, *C. pygmaeus*, first reported in Ontario in a meadow near Ottawa in 1887 (Harrington, 1890), was first recorded as damaging wheat in Ontario in the counties of Hastings, Prince Edward, and York in 1938. It was a serious pest in New York and Pennsylvania in the early 1920's (Ries, 1926). As *C. cinctus* was a major pest of wheat in Western Canada and *C. pygmaeus* a pest in New York and Pennsylvania, the discovery of moderate to heavy infestations of *C. pygmaeus* in several localities in south-central Ontario in 1939 by Mr. G. H. Hammond, Entomology Field Station, Marmora, caused concern about the future importance of the sawfly as a pest of wheat in Ontario. *C. calcitrator* was being imported from England for release against *C. cinctus* in Western Canada at the time and advantage was taken of the opportunity to release the parasite in Ontario as a possible aid in control.

[1]Contribution No. 3927, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada.

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Colonies of approximately 1,600 females and 800 males of *C. calcitrator* were liberated in 14 localities in south-central Ontario in June, 1940, and one small colony of 160 females and a large number of males was released at Codrington in early July.

The progress of the parasite was followed by means of late-summer collections of mature sawfly larvae in wheat stubs, stored for several months at 0° C. and then incubated at 24° C. for emergence of sawflies and parasites. The establishment of *C. calcitrator* and the status from 1940 to 1946 of this and other parasites of the sawfly were reported previously (Smith, 1948). Subsequent collections showed a marked increase in parasitism by *C. calcitrator* from 1947 to 1949. Regular collections were discontinued in 1950 because of the scarcity of the host. However, occasional subsequent sampling showed *C. calcitrator* to be present under conditions of extreme host scarcity, and a more thorough sampling was attempted in 1958.

Late in the summer of 1958 collections of sawfly larvae in wheat were made from a majority of the parasite colonization areas in Ontario. Wheat fields were extremely scarce in several, and in some fields no sawfly infestations were found. In none of the fields did the number of stems infested by the sawfly exceed one per cent, and in a few it was less than one per thousand. *C. calcitrator* was found in all localities where collections were made, though the samples were small in most instances. In 1958, parasitism was determined from dissections of sawfly larvae rather than from rearings.

The continued increase in the average parasitism by *C. calcitrator* since its release in 1940 is evident in Table I. In many localities, however, there was no evidence of its establishment for five or more years after its release, and little evidence of a definite increase until 1947, seven years after its release.

The recovery of *C. calcitrator* at Codrington in 1958 was of special interest for it was the only colonization area in which it had not previously been taken. The delayed recovery in this area may be the result of a slow increase from a small colony (160 females) or of dispersal from larger colonies established 18 miles distant. Recoveries at Solina and Napanee (b) were made from sparse populations of sawflies five miles from the original point of release.

The establishment and increase of *C. calcitrator* in Ontario on *C. pygmaeus* is in marked contrast to its failure to establish on *C. cinctus* in Western Canada. From 1930 to 1939 approximately 500,000 of *C. calcitrator* were released against *C. cinctus* in the Prairie Provinces, but there is no present evidence of its establishment. The parasite was recovered from late-summer collections of sawflies each year after early-season releases, and it was also recovered two years after releases. However, parasitism never exceeded 13 per cent and was more often less than one per cent. In heavy sawfly infestations, such as occurred in Western Canada, many sawfly eggs are often found in one stem; and as only one sawfly larva survives per stem, many eggs and larvae are destroyed by the surviving larva. As *C. calcitrator* deposits its egg in the egg of the sawfly it, too, is subject to all the risks of host cannibalism. In addition, *C. calcitrator* larvae suffer 30 to 50 per cent mortality in *C. cinctus,* perhaps because of physiological unsuitability of this host.

The success of *C. calcitrator* on *C. pygmaeus* in Ontario may be due to suitability of the host, synchronization in the development of the parasite and host, and in part to environmental factors.

The other internal parasite of *C. pygmaeus* in Ontario is *Pediobius beneficus* (Gahan). It is undoubtedly a European species introduced with its sawfly host,

TABLE I

Percentages of *C. pygmaeus* parasitized by *C. calcitrator*, and average parasitism by *P. beneficus*, in south-central Ontario, 1940 to 1949 and 1958

Locality	Percentage parasitism (and number of hosts collected)										
	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1958
Newmarket	0(394)	0(298)	t(344)	0(192)	0(130)	1(105)	4(133)	28(99)	54(11)	31(42)	56(16)
Stouffville	0(202)	t(191)	0(104)	2(144)	2(155)	16(88)	5(115)	23(109)	11(53)	8(40)	– –
Sandford	0(207)	0(298)	0(99)	t(225)	6(101)	12(69)	13(91)	35(113)	37(59)	37(35	– –
Myrtle	0(66)	– –	0(8)	– –	– –	3(67)	– –	33(57)	21(24)	0(4)	100(4)
Solina	0(45)	– –	0(50)	2(94)	0(20)	22(9)	5(42)	13(111)	23(35)	32(22)	100(7)
Bethany	0(221)	0(314)	0(31)	0(173)	0(58)	10(21)	– –	16(37)	32(104)	0(5)	– –
Oakwood	0(157)	1(416)	0(63)	1(109)	4(50)	9(43)	10(41)	34(47)	33(3)	0(1)	32(22)
Lindsay	0(204)	0(121)	0(3)	13(115)	8(229)	10(88)	9(11)	44(68)	18(28)	– –	– –
Indian River	0(93)	0(95)	– –	0(36)	0(51)	0(12)	– –	12(8)	0(23)	– –	– –
Codrington	0(133)	0(131)	0(36)	0(40)	– –	0(17)	0(53)	0(35)	0(69)	0(3)	12(8)
Harold	0(365)	0(565)	2(290)	2(170)	3(38)	8(52)	– –	18(40)	0(3)	– –	56(16)
Halloway	0(110)	– –	– –	– –	– –	– –	3(43)	0(3)	– –	– –	– –
Chatterton	1(414)	t(296)	– –	– –	– –	– –	0(19)	24(119)	29(7)	– –	49(63)
Belleville	– –	t(214)	– –	– –	– –	– –	– –	14(29)	– –	– –	67(3)
Napanee (a)	0(35)	– –	3(32)	– –	– –	– –	8(12)	0(2)	– –	42(31)	40(20)
(b)	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	27(15)
Total	(2646)	(2939)	(1060)	(1328)	(792)	(571)	(550)	(877)	(419)	(183)	(174)
Av. *C. calcitrator*	t	t	1	2	4	8	6	25	21	27	47
P. beneficus	11	8	19	15	30	15	27	20	13	7	2

t = Trace.

and was already present in Ontario when *C. calcitrator* was released in 1940. In that year, parasitism by *P. beneficus* exceeded 20 per cent in some localities. Salt (1931) considered this parasite to be intrinsically inferior to *C. calcitrator* and that it survived only in hosts in which *C. calcitrator* was absent. The evidence from the Ontario records, though meagre, supports Salt's conclusion. A marked increase in parasitism by *C. calcitrator*, beginning in 1947, was followed by a marked decrease in parasitism by *P. beneficus* (Table I). Records of parasitism for 1958, (Table I) are probably reliable for *P. beneficus* though some of the very small larvae may have escaped detection in dissections.

Summary

Collyria calcitrator (Grav.) was imported from Europe and released in a number of localities in south-central Ontario in 1940 against *Cephus pygmaeus* (L.) Average annual parasitism by this species had reached 8 per cent by 1945 and 27 per cent by 1949. A survey in 1958 showed that the average parasitism was 47 per cent, and that the parasite had spread from some of the original release areas. Increased parasitism by this species was associated with a decrease in parasitism by *Pediobius beneficus* (Gahan), another internal parasite, probably of European origin.

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Resistance in Rutabagas to the Cabbage Maggot, *Hylemya brassicae* (Bouché) (Diptera: Anthomyiidae)[1]

By G. E. Swailes

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Resistance in plants to the cabbage maggot, *Hylemya brassicae* (Bouché), has not been investigated extensively. Glasgow (1925) and Whitcomb (1944) compared the percentages of infestation of species of cruciferous crops and varieties of cabbage. Whitcomb (1944) attributed differences in degree of injury among 13 cabbage varieties to resistance in the plants rather than to repellent action during oviposition. He observed that the faster-growing varieties of cabbage were more susceptible to injury. The investigations reported herein were designed to determine if rutabagas had resistance to the cabbage maggot.

Methods and Materials

In 1955, puparia were collected from nine rutabaga varieties grown near Lethbridge, Alberta. They were taken from 50 feet of row of each variety and weighed. In 1956, six of these varieties grown in the same place were rated for damage in the fall. In that year four replicates of 40-foot rows of the same varieties were planted at the Canada Agriculture Research Station, Lethbridge. From a single plant selected at random in each row eggs were removed and counted; the plant was pulled and the soil around it was examined for puparia;

[1]Contribution from the Entomology Section.

and the root was pared carefully and examined for larvae, especially around those areas that showed damage. This procedure was carried out at weekly intervals from July 14 to September 14 and then at two-week intervals until October 25.

In 1958, 13 rutabaga varieties were each grown in three replicates. Eggs were collected and counted from two plants in each replicate at approximately four-day intervals from August 7 to September 11. Puparia were collected in October from two different plants of each variety from each replicate.

Results and Discussion

Consistent differences in extent of damage and number of puparia were evident between varieties. The 1955 data showed that different numbers of puparia were associated with different varieties of rutabaga (Table I). The similarity of pupal weights indicated that all varieties had similar nutritional value for the maggots.

TABLE I

Numbers and weights of *Hylemya brassicae* puparia on nine varieties of rutabaga at Lethbridge in 1955

Variety	Puparia		
	Number in 50 ft. row	Average weight (mgm.)	Range of weights
Ditmars Bronze Top	98	16.2	11.2 — 23.2
Lord Derby	62	16.9	10.2 — 21.3
Selected Purple Top	57	16.8	12.3 — 21.6
Canadian Gem	57	16.5	12.4 — 21.0
Westbury	46	17.3	12.0 — 22.7
Kangaroo	41	16.7	9.4 — 22.0
Laurentian	27	16.9	13.2 — 19.9
Jumbo	13	16.9	13.3 — 22.3
Wilhelmsburger	11	16.1	13.1 — 19.0

In 1956, where the density of the adult population was low, the percentages of plants of six varieties that were damaged were:

Ditmars Bronze Top	40
Westbury	28
Selected Purple Top	26
Laurentian	25
Canadian Gem	25
Wilhelmsburger	12

The order of damage followed the same order as for number of puparia (Table I). Under conditions of high density of adults in the same year the numbers of puparia from these varieties were in almost the same order as in 1955 (Table II).

In the 1958 field tests, comparison of the numbers of puparia from fall collections with the numbers of eggs laid by the late-summer flight resulted in survival ratios as given in Table III. The numbers of puparia from Lord Derby were low, possibly because the roots were abnormally smaller in this variety than in the others.

Duncan's multiple range test showed that significantly more eggs were laid on Canadian Gem than on Westbury, Johnson's Favorite, Victory Neckless,

TABLE II
Infestation and survival of *Hyiemya brassicae* in six rutabaga varieties at Lethbridge in 1956

Variety	Average number from four plants		Percentage survival
	Eggs	Puparia	
Ditmars Bronze Top	59.7	12.0	20
Canadian Gem	50.7	7.7	15
Westbury	59.0	6.0	10
Selected Purple Top	44.0	4.5	10
Laurentian	32.5	1.7	5
Wilhelmsburger	48.2	1.5	3

Alta Sweet, Golden Table, Laurentian, and Yellow Bronze Top. There were no significant differences among the other varieties. The variability in egg and pupal numbers between plants within a variety was high.

In the laboratory, plants of four varieties in each of two tests were examined for oviposition preference by placing potted plants in a large cage in which flies were released. The number of eggs laid on Wilhelmsburger was not significantly lower than the numbers laid on other varieties. The numbers of eggs were:

1.	Wilhelmsburger	46
	Ditmars Bronze Top	42
	Canadian Gem	53
	Lord Derby	102
2.	Wilhelmsburger	252
	Laurentian	294
	Selected Purple Top	171
	Westbury	229

Similarly, the numbers of eggs did not differ significantly between Wilhelmsburger and the other varieties in the two years in which eggs were collected in the field (Tables II and III).

Wilhelmsburger showed the least damage and produced the fewest puparia in all tests. As this variety is equally preferred for oviposition, a resistance to

TABLE III
Infestation and survival of *Hylemya brassicae* in six rutabaga varieties at Lethbridge in 1958

Variety	Average number from six plants				Percentage survival
	Eggs	s.d.	Puparia	s.d.	
Westbury	118	58	30	22	25
Yellow Bronze Top	53	25	13	7	25
Ditmars Bronze Top	138	91	28	14	20
Selected Purple Top	141	71	28	8	20
Golden Table	65	44	13	8	20
Laurentian	54	42	10	4	19
Victory Neckless	87	79	14	8	16
Canadian Gem	245	100	38	16	16
Alta Sweet	84	48	12	8	14
Golden Neckless	155	128	21	19	14
Johnson's Favorite	109	60	11	2	10
Lord Derby	179	104	11	11	6
Wilhelmsburger	159	42	7	5	4

the establishment and/or the growth of the larvae is indicated. This variety also gave the lowest percentage survival calculated from the puparium to egg ratio (Tables II and III). Since all varieties seem to be nutritionally similar on the evidence of similar pupal weights (Table I), ease of larval establishment must be the important factor in differences in resistance among these varieties.

The variety Ditmars Bronze Top was the most susceptible to damage and supported the highest population in two of the experiments and was the third variety in 1958 for percentage survival of the maggots. It was one of the fastest-growing varieties and supports Whitcomb's (1944) suggestion that a fast rate of growth is correlated with susceptibility.

Laurentian, which is the commonly grown variety in southern Alberta, had a small number of puparia in all tests but this could have been the result of oviposition preference as this variety had a low number of eggs in the two field studies. The percentage survival (Table III) is moderately high on Laurentian.

Summary

Wilhelmsburger possesses resistance to the development and for establishment of larvae of the cabbage maggot. Of the varieties tested Ditmars Bronze Top was the most susceptible to the maggot. Laurentian, a commonly grown rutabaga in southern Alberta, may have some resistance to larvae and some resistance to oviposition.

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An Unusual Case of Teratology in Siphonaptera

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Most systematists occasionally come upon abnormal specimens of species belonging to the groups they study. Such specimens, depending on the nature of the abnormality, may be of only passing interest as curiosities, or may be considered of sufficient importance to report in the literature.

Several authors have recorded cases of teratology in the fleas, most of the cases concerning duplication of an organ (usually the spermatheca of the female), castration of the male by nematodes, or variability in the numbers of ctenidial spines. Smit (1949) reviewed the scant literature and later published several additional papers on monstrosities in Siphonaptera.

That important theories may be developed by the study of certain abnormalities was well illustrated by Jordan (1947), who postulated from a study of "pathological" specimens (species unrecorded) that the ctenidial spines on the dorsal region of thorax and abdomen, so characteristic of most species of fleas, originated from "pseudosetae" such as are found under the flange of the mesonotum of many fleas, and under the pronotum of some vermipsyllids and parapsyllids. This led him to consider that vermipsyllids, for example, are the end-products of lines of descent in which pronotal combs were never developed,

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whereas, such fleas as combless pulicids and hystrichopsyllids are descended from ancestors that probably had such combs but have since lost them. If Jordan was correct, then in many species of fleas to-day there are several stages of comb-development on the various dorsal sclerites of each individual. In the Ceratophyllidae, for example, pseudosetae on the mesonotum would represent rudimentary combs; the pronotum usually bears a fully-developed comb of heavy spines; and the metanotum and anterior abdominal terga have a few apical spinelets that may be considered vestigial combs.

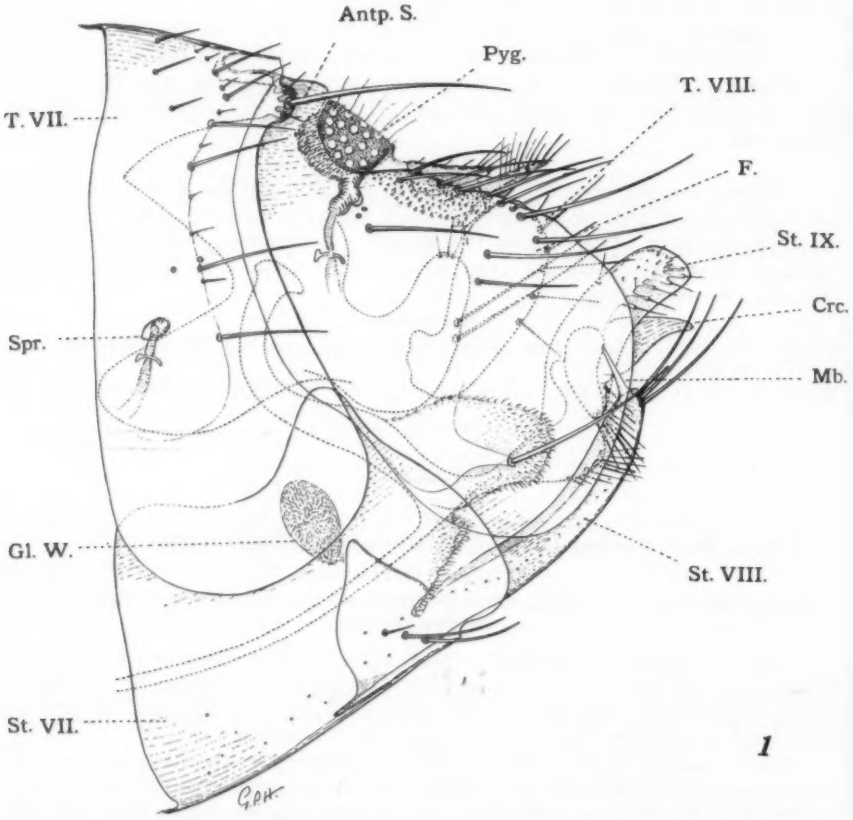


Fig. 1. *Ceratophyllus lari* Holl. Terminal abdominal segments and genitalia of normal male.

In this paper a remarkable male flea, one of the numerous paratypes of *Ceratophyllus lari* Holland 1951, and mentioned in another paper (Holland, 1957), is considered. This specimen has characters on the penultimate abdominal segments that suggest earlier evolutionary stages leading to the characteristic modifications of the group (Ceratophyllinae) to which it belongs.

The specimen is apparently normal in all respects except for the modified abdominal segments (VII and VIII) that enclose and protect the terminalia and for very slight malformation of the clasper processes.

As in all Ceratophyllinae (see Snodgrass, 1946, and Holland, 1955, for fuller accounts), the anterior abdominal segments of *C. lari* are unmodified except for the absence of sternum I. The ventral margins of the terga overlap the corresponding sterna on either side. Each tergum has a strong row of setae posteriorly and a weak row anteriorly. Spiracles open laterally on the terga, and terga I-V bear, in addition to setae, one or two apical spinelets (Fig. 3) on each side. These spinelets, which are apparently the vestiges of true ctenidial spines, arise directly from the integument, and are not articulated in alveoli as are the

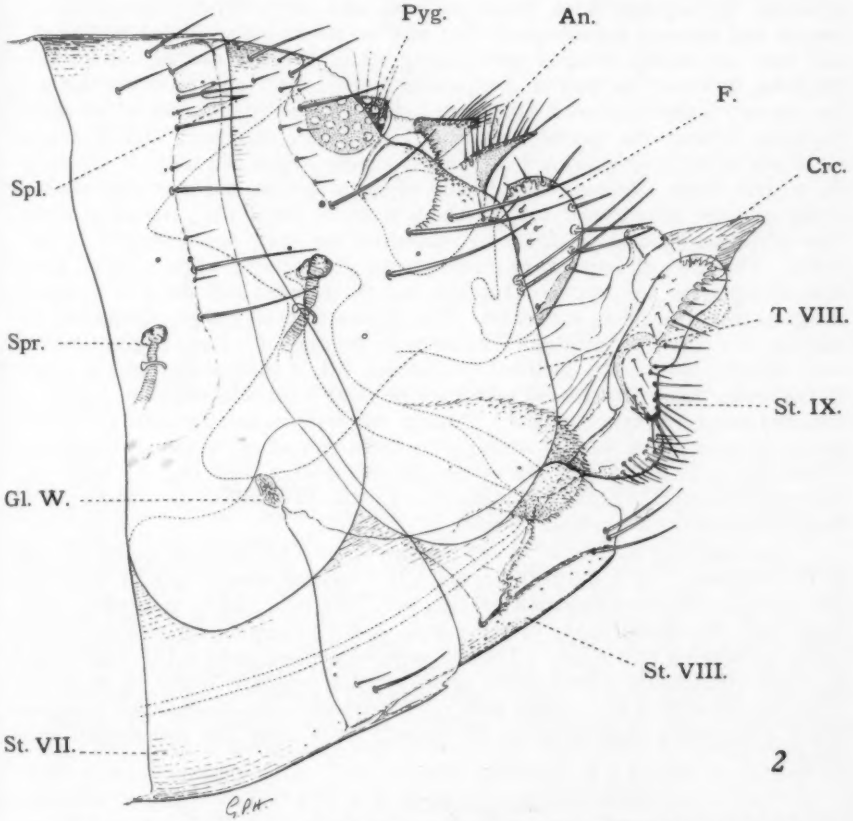


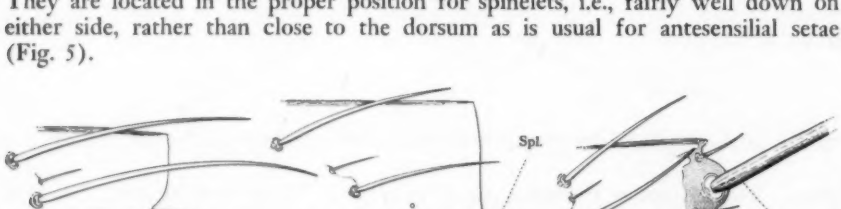
Fig. 2. *C. lari* Holl. Terminal abdominal segments and genitalia of abnormal male.

setae. Though apical spinelets occur on tergum VI in some species, they are known to occur normally on tergum VII only in species of *Uropsylla* Rothschild (Pygiopsyllidae) and *Stenischia* Jordan (Hystrichopsyllidae). In most fleas, including all species of *Ceratophyllus* Curtis, they are "replaced" on tergum VII by one or a group of (usually three) long, stout, antesensilial setae, which originate on protuberances on the posterodorsal margin of the sclerite, on either side (Figs. 1, 5). These setae project caudad to protect the sensilium; except for their presence, abdominal segment VII does not differ essentially from the preceding segments.

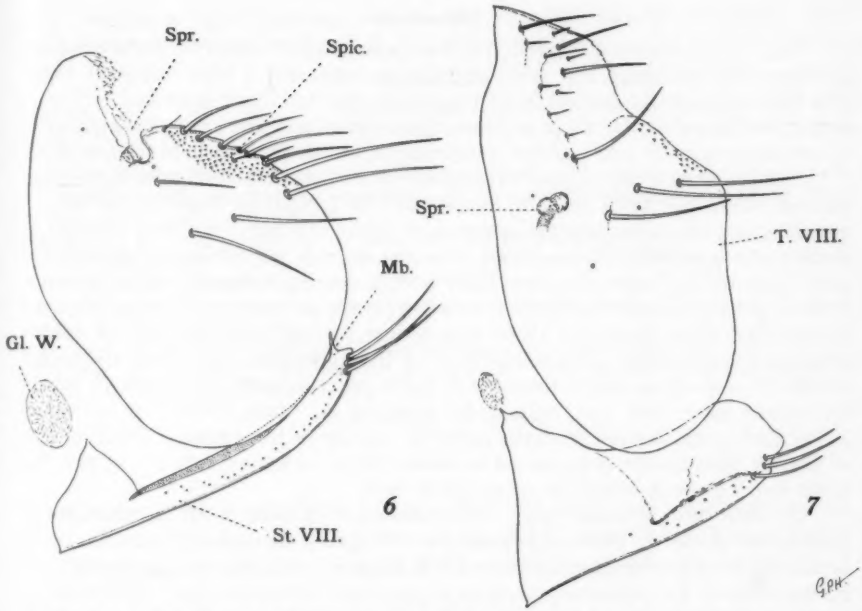
Abdominal segment VIII is strongly modified in the males of most fleas, usually so as to protect the claspers and aedeagus. The spiracles of this segment do not open laterally, but instead open on the inner dorsal margin of the tergum, on either side of the sensilium (Figs. 1, 6). The atrium is larger than in the anterior spiracles.

The proportions and vestiture of tergum and sternum VIII provide valuable taxonomic characters for families of Siphonaptera. In the Pulicidae, for example, the tergum may be very small – little more than a frame for the spiracle, whereas sternum VIII is expanded into a pair of broad valves enclosing the genitalia. In Leptopsyllidae, Ischnopsyllidae, and many Hystrichopsyllidae the tergum and sternum are subequal; they may be somewhat expanded posteriorly, and they are usually fringed with strong setae, directed caudad. In Ceratophyllidae, however, the tergum is expanded into a broad valve on either side and the sternum is much reduced, usually to a slender rod-like structure which closes the space between the ventral margins of the tergum. Segment VIII of normal specimens of *Ceratophyllus lari* is typically ceratophyllid (Figs. 1, 6). Dorsally the tergum forms a narrow arch anterad of the sensilium, and then expands into a pair of large sub-circular valves, which virtually cover the external genitalia. The spiracular opening is large, and located on the inner dorsal margin of each valve. The rows of setae, so characteristic of the anterior terga, are lost, but a few strong setae are scattered laterally on the sclerite, and there is a dorsal, marginal row of eight or nine setae. On the inner dorsal margin, caudad of the spiracle, is a patch of spicules. The sternum consists of a long, slightly curved rod. Basally, where it is enclosed by sternum VII, it extends upwards in a pair of triangular flaps. Associated with each of these is an oval organ of uncertain function termed Wagner's gland. Distally, the sclerite terminates in a crowded group of about three pairs of strong setae and a pair of apical membranous flaps which are small and finger-like in this species, though they may be large and elaborately fringed in others. Ventrally, segments VIII and IX are connected by hairy membranes that project as lobes.

The teratological male of *C. lari* exhibits abnormalities on segments VII and VIII. Sternum VII is normal; tergum VII is normal except that the modified antesensilial setae are completely lacking on either side. More surprising, however, than the mere absence of these setae, is the presence of a well developed apical spinelet on either side. Though somewhat more slender (cf. Figs. 3 and 4), these spinelets are as long as the apical spinelets regularly found on terga I-V. They are located in the proper position for spinelets, i.e., fairly well down on either side, rather than close to the dorsum as is usual for antesensilial setae (Fig. 5).



Figs. 3-5. *C. lari* Holl. 3, Posterodorsal margin of tergum II showing normal apical spinelets. 4, Same, of tergum VII of abnormal male, showing apical spinelet in place of antesensilial setae. 5, Same, of tergum VII of normal male, showing antesensilial setae.



Figs. 6-7. *C. lari* Holl. 7, tergum and sternum VIII of normal male. 8, Same, of abnormal male.

Segment VIII is even more unusual. The tergum is not unlike the preceding terga, in that it is long and narrow, and only slightly rounded caudad. The dorsal part is relatively broad, and has one major row of setae and a scattering of thin setae as do the anterior terga. There is no row of marginal setae as in normal specimens, but three lateral setae are in approximately the normal position (cf. Figs. 6 and 7). The dorso-posterior margin of the tergum bears a few spicules, but not a full complement. However, the presence of the spiracle on the lateral surface of the tergum rather than on its inner dorsal margin is truly remarkable; only one other such instance is known, in the unique type female of *Hystrichopsylla kris* Traub and Johnson, which, too, is almost certainly abnormal (Holland, 1957). The spiracles on segment VIII of the present specimen are exactly like those of the anterior segments, and not at all like the modified spiracle of the normal segment VIII. Only a slight indication of a groove or channel on the dorso-posterior surface indicates where the opening should be.

The sternum shows corresponding abnormalities. Its lateral elements are intact rather than reduced, and it is only slightly shallower than the anterior sterna. Its dorsal margins are slightly overlapped by the apical margins of tergum VIII, and the proximo-dorsal apex on either side is associated with a miniature Wagner's gland (cf. Figs. 6 and 7). An internal thickening subventrally suggests a stage in the development of the typical rod-like form. The apical setae are not so closely grouped as in normal specimens but extend slightly onto the lateral elements of the sclerite, suggesting the arrangement on anterior sterna. Apical flaps are not differentiated.

Sternum IX and the genitalia are apparently normal, but the movable process of the clasper is slightly reduced (cf. Figs. 1 and 2). The sensilium is somewhat telescoped under tergum VIII but may have been exposed in life.

Discussion

The writer does not suggest that the genetic coincidence or embryological accident that produced this specimen has demonstrated a true ancestral form. The flea is apparently normal in all respects except for those described. Nevertheless, he feels that the abnormalities of this individual may suggest homologies of certain structures and perhaps something of the evolutionary history of fleas.

Apical spinelets on tergum VII cannot, of course, be homologous with antesensilial setae, but they may be analogous. In *Uropsylla tasmanica* Roths., a primitive flea of marsupials, the presence of apical spinelets (not long enough to protect the sensilium) is associated with the absence of thickened antesensilial setae (present in all other Pygiopsyllidae). It is usually assumed that the presence of true spines and spinelets represents a more primitive state, and that the presence of modified setae, especially those that appear to take over the role of spines, indicates specialization. In the bat fleas, or Ischnopsyllidae, extensive abdominal combs of true spines are common, but there are a number of species in which the combs have been lost, only to be replaced by "false combs" of modified (thickened) setae derived from the posterior row on each segment. The function of true or false combs is presumed to be the same, to ensure security of the flea while moving about in the fur of an active host.

In Hystrichopsyllinae (e.g., *Hystrichopsylla* Roths., *Atyphloceras* Jord., *Stenoponia* Jord. & Roths., *Typhloceras* Wagn.), the spiracle proper, with occluding device, is situated laterally inside tergum VIII, but a long, channel-like atrium leads to the customary position on the inner dorsal margin. This may be considered a fairly primitive condition that was probably preceded by the spiracle opening laterally as in the type specimen of *Hystrichopsylla kris* already mentioned, and as in the aberrant male of *Ceratophyllus lari*.

Comparison between the terga VIII of normal and abnormal *C. lari* suggests that the marginal group of setae on the former may be homologous with the major row occurring on "unmodified" terga. In the abnormal specimen, there is an almost typical row of setae, of which the two lowermost are in virtually the same position as the major row on anterior terga. It seems possible that the remaining setae have "migrated" to a marginal or near marginal position, i.e., that in the normal tergum VIII these represent the same setae shifted to a new position, rather than new setae.

With the general broadening of tergum VIII it seems there has been a concurrent reduction of the lateral elements of sternum VIII until, in modern ceratophyllids, these are represented only by proximal and distal flaps arising from a slender rod. Sternum VIII of the abnormal specimen may not represent a true evolutionary step between a primordial, unspecialized, sternum and the highly modified sclerite of contemporary ceratophyllids, but it certainly suggests a possible stage.

Summary

An abnormal male of *Ceratophyllus lari* Holland is described and compared with normal specimens of the species. The teratological specimen has apical spinelets rather than antesensilial setae on tergum VII, and almost entirely lacks the normal modification of tergum and sternum VIII, an especially unusual feature being a lateral, rather than a dorsal, marginal spiracle. Speculations are offered on the evolutionary significance of these characters, and on some homologies.

Abbreviations Used in Illustrations

An.; anus; Antp. S., antesensilial setae; Crc., crochet; F., movable process of clasper; Gl. W., Wagner's gland; Mb., membranous appendage of sternum VIII;

Pyg., sensilium; Spic., spiculose area of tergum VIII; Spl., apical spinelet; Spr., spiracle; St., abdominal sternum; T. abdominal tergum.

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Morphology of Immature Stages, Life-History, and Behaviour of Three Hymenopterous Parasites of the European Pine Shoot Moth, *Rhyacionia buoliana* (Schiff.) (Lepidoptera: Olethreutidae)[1]

By J. A. Juillet[1]

Three introduced species of hymenopterous parasites of the European pine shoot moth, *Rhyacionia buoliana* (Schiff.), were released in Waterloo County Reforestation Area, near Elmira, Ontario, from 1955 to 1957: *Ephialtes ruficollis* (Grav.) and *Eulimneria rufifemur* (Thoms.) (Ichneumonidae) and *Tetrastichus turionum* (Htg.) (Eulophidae). This is an account of their life history and behavior.

Thorpe (1930) reported that *E. ruficollis* is widely distributed throughout northern and central Europe. Rearings from recent importations of pine shoot moth larvae showed that it is less important in continental Europe than in England, where it is one of the three most abundant parasites of *R. buoliana*. The parasite was introduced into southern Ontario from England and 7,032 adults were released from 1933 to 1942, but none was recovered (Coppel and Arthur, 1954). From 1955 to 1957, 4,382 individuals were liberated.

E. rufifemur is one of the four most abundant parasites of the moth in Europe. It was first released in Canada in 1935, when 797 adults were liberated in southern Ontario (Coppel and Arthur, 1954). No recovery was made. From 1955 to 1957, 952 adults were released.

T. turionum is one of the three most important species that attack *R. buoliana* in Austria (Dowden, 1934) and Sweden (Ruschka, 1924) and is found throughout continental Europe. It was first introduced into Canada from Europe in 1938, when 1,570 adults were liberated (Coppel and Arthur, 1954). Recoveries were made in 1939 and later in the area of release. From 1955 to 1957, 1,162 adults were liberated.

Materials and Methods

Adult parasites were obtained from release shipments and held in oviposition cages or an outdoor cage (Nicholls, 1958). *E. ruficollis* was reared on larvae of the greater wax moth, *Galleria mellonella* (L.); *E. rufifemur* on larvae of the

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Indian-meal moth, *Plodia interpunctella* (Hbn.); and *T. turionum* on pupae of its normal host, *R. buoliana*.

In the laboratory, the hosts were exposed to parasitism for 24 hours. They were then removed from the oviposition cages and reared individually. At intervals, numbers of the hosts were dissected to obtain the immature stages of the parasites.

In the field cage, four small red pine trees heavily infested with larvae of *R. buoliana* formed a restricted, but natural, habitat. The temperature and humidity were recorded by a hygrothermograph. Behavior was studied by following the activities of individuals for as long as possible. This was repeated many times under all types of weather conditions with each species.

The release area was in a plantation of red pine trees that were about 10 years old and that varied in height from three to 12 feet. The activity and rate and pattern of dispersal of the adult parasites were studied after each release and these observations were associated with the weather conditions.

Ephialtes ruficollis (Grav.)

Descriptions of Immature Stages

Egg (Fig. 1).—Elongate, with one end slightly broader than the other; chorion smooth on both ends, but intermediate portion with a uniform, tubercle-like pattern; opaque-white, turning yellow with development of embryo; measurements of 10 eggs: length 2.25 mm. (range 2.10 to 2.40), greatest width 0.35 mm. (0.32 to 0.42).

Larva.—Thorpe (1930) illustrated and briefly described the larva. All five instars: hymenopteriform; white or yellowish; 13 body segments; more or less fusiform (Fig. 3) except in first instar (Fig. 2), which tapers from the head posteriorly; nine pairs of spiracles, on the last two thoracic and the first seven abdominal segments.

A gradual increase in sclerotization of the head capsule and in the number of setae and a decrease in the size of the two-segmented antennae in relation to the size of the head occur with each instar. Maxillary and labial palpi become evident as light traces in the fourth instar, and are well defined only in last instar (Fig. 4). The silk duct appears in the third instar, but is not open until the fourth. Sclerotization of the vertex shows weakly in the fourth instar. The right mandible of each instar and the spiracle of the last instar are shown in Figs. 5 to 10.

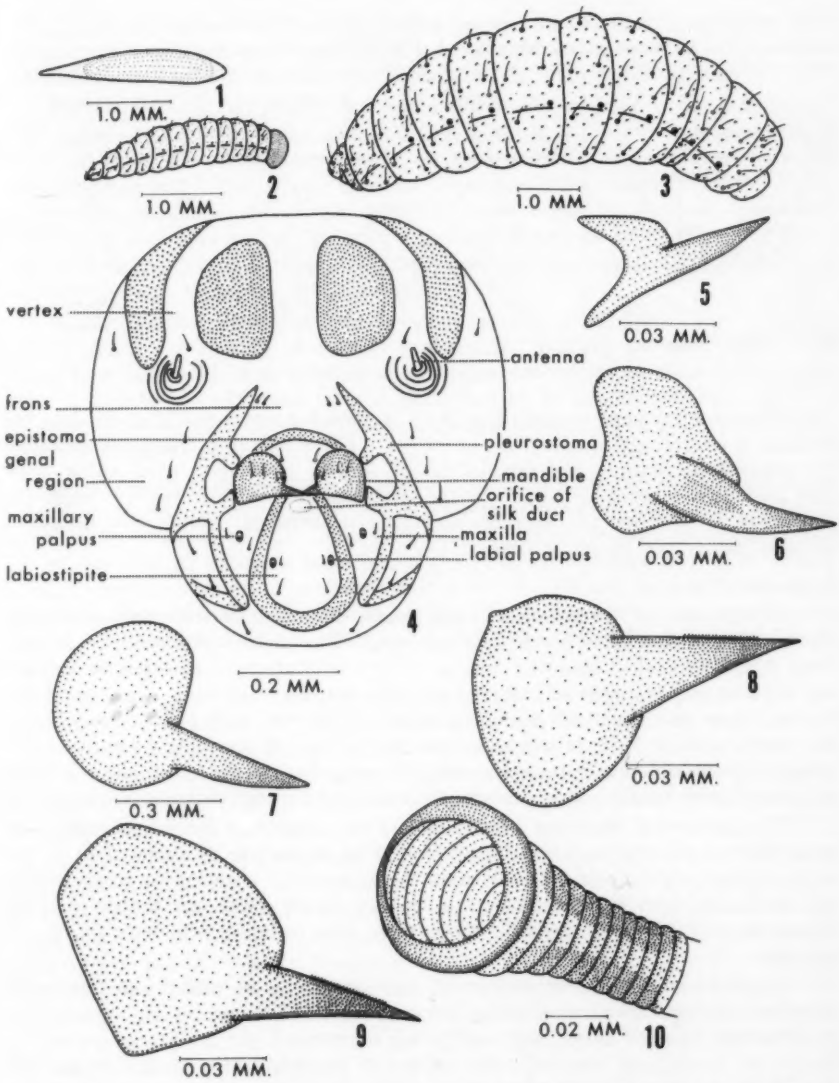
The average measurements in millimeters of the five larval instars, based on approximately 15 specimens each, are as follows:— first: length 2.54, width 0.61, width of head capsule 0.32; second: 3.52, 0.85, and 0.47; third: 4.45, 1.19, and 0.59; fourth: 5.73, 1.53, and 0.72; fifth: 7.40, 2.06, and 0.84.

Cocoon.—Irregular in shape; made of loosely spun, white silk through which the pupa is visible. Thorpe (1930) reported that frequently the species spins no cocoon when reared in gelatin capsules.

Life-History

E. ruficollis pupates in the spring and the adult emerges in about two weeks. In England the adults emerge from early June to late August (Thorpe, 1930). Though Thorpe reported that the male was unknown, 45 per cent of the adults that emerged from the English material reared at Belleville were males.

Mating usually occurs upon emergence of the female and oviposition may commence up to 29 days later. Four molts occurred, all within six days after hatching. The five instars lasted, one to three, one, one to two, two, and five to seven days respectively at an average temperature of 76° F.



Figs. 1-10. *E. ruficollis*. 1, Egg. 2, First-instar larva. 3, Fifth-instar larva. 4, Head capsule of fifth-instar larva. 5-9, Right mandible of larva. 5, First instar. 6, Second instar. 7, Third instar. 8, Fourth instar. 9, Fifth instar. 10, Spiracle of fifth-instar larva.

The first-instar larva always feeds in the intersegmental fold, whereas the other instars feed anywhere on the host. The first-instar larva usually wanders a little on the host before molting and the other instars often wander on and beside the host larva.

When the mature larva is ready to pupate, it leaves the host and spins its cocoon. The prepupa appeared within approximately two days and lasted for about four days at an average temperature of 76° F.

TABLE I.

Various details of life histories of the three introduced parasites.

	E. ruficollis	*E. rufifemur*	*T. turionum*
Type of parasitism	External, larval	Internal, larval	Internal, pupal
Overwintering stage	Mature larva	First-instar larva	Mature larva
Duration of life, days			
Male	26	13	16
Female	52	27	27
Preoviposition period	10–29	3–21	3–4
Oviposition period	27–39	5–18	2–10
Postoviposition period	6–27	2–20	12–25
Egg	2–3	3–4	2
Larva	10–15	310±	320±
Pupa	7–13	20±	10±
No. of larval instars	5	5	4

The time from egg to adult was 26 to 30 days for males and 27 to 34 days for females at an average temperature of 76° F. There are only two generations of the parasite per year. The females of the second generation presumably must find larvae of a secondary host, as the larvae of *R. buoliana* are too small for parasitism at the time the parasites are ready to oviposit. Additional details of the life history are given in Table I.

Behavior of Adult

Copulation.—In the laboratory, the species copulates most commonly during the first few hours after the female emerges. The male is attracted by a pupa from which a female is about to emerge. Very soon after she emerges, he mounts her dorsum without apparent courtship. The female often runs away, or, if she is more than one hour old, fights the male. However, if the male immobilizes her wings with his front legs, mating usually occurs. If the female can move her wings, copulation lasts 30 to 40 seconds; if she cannot, 90 to 135 seconds. After copulation, the female usually rejects the male, who avoids fighting with her.

Copulation was observed three times in the outdoor cage. Each time, the male flew around a resting female and landed on a pine needle about eight inches away. After a short rest the male took flight, hovered within four to six inches of the female, and then attempted to mate. In all cases the female quickly turned around, biting at the male, so that the time in coitus was only five to 10 seconds.

Oviposition.—The attractiveness of the host larvae to the female gradually increases during the preoviposition period. In the laboratory, the female approaches an infested shoot, feels with her antennae for the aperture, and, on finding it, introduces the ovipositor as far as possible. When she touches the host larva, the female suddenly probes rapidly with her ovipositor, piercing the host larva until the latter is motionless. After the host is paralysed, the female usually lays one or two, seldom more, eggs on or beside the host larva. Only one parasite larva usually matures on one host.

Seven females laid 159 eggs in 34 days, an average of about 23 eggs per female. Dissection of two females that laid 10 eggs each and were near the end of the oviposition period revealed that eight and 10 mature eggs remained in their ovaries and 64 and 62 oocytes in the ovarioles. The reproductive potential of the species therefore probably is approximately 82 eggs per female.

Oviposition occurred in the outdoor cage and release area when the weather was favorable (60° to 80° F., wind of five miles per hour or less). The female

investigates the infested buds of the upper portion of the tree at optimum conditions, but at temperatures well above the optimum or at wind velocities above five miles per hour she searches lower branches or well-protected buds.

Feeding.—Males fed readily on raisins and honey solution in the laboratory. The female fed less than the male during most of the pre-oviposition period. The females killed and fed on many host larvae just before and throughout the oviposition period. The female uses her ovipositor in the typical pumping action to increase the size of the wound and then feeds avidly on the body juice that exudes. *E. ruficollis* is thus not only a parasite during its larval stage but also a predator during its adult stage. This predation might deprive the progeny of sufficient food to complete development.

In the outdoor cage and release area, females often drink dew from the undersides of the needles in the early morning. During the day, they often pierce new buds with their ovipositors and apparently feed on the exuding resin. Once a female was observed in, and presumed to be feeding at, the cup of a blossom of the bladder campion, *Silene cucubalus* Wibel. The males were never observed drinking anything but dew.

Flight.—Both males and females start flying at about 60° F. if the wind is less than three to five miles per hour. In a stronger wind they do not fly until the temperature is about 65° F. The flight of the female reaches a peak at about 75° F., but that of the male requires a slightly higher temperature. The female ceases flying at about 80° F. and the male at 85° F. When the wind velocity is above five miles per hour, the insect is seen flying in protected places. Normal variations in humidity did not affect the flight of the adults, but rain forced them to cease flying.

The female assumes two characteristic postures in flight, depending on the type of flight. In dispersal flights the body is usually held at an angle of 20° to 30° to the horizontal; in oviposition flights, at 60° to 70°. In both cases the abdomen and the ovipositor are held in almost a straight line. Unlike the female, the male in flight holds the body in an almost horizontal position with the tip of the abdomen curved upward.

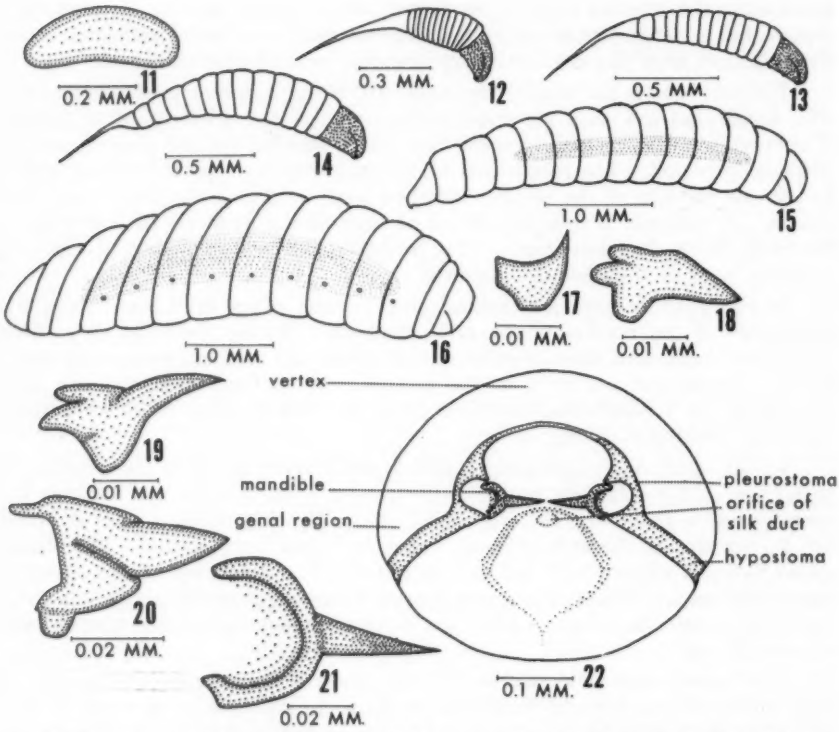
Rate and Pattern of Dispersal.—Wind and temperature affect the dispersal of *E. ruficollis* considerably. The rate of dispersal in the release area appeared to be at its maximum at wind velocities of less than five miles per hour and at a temperature of about 75° F. Under these conditions, 22 parasites were recaptured an average of 80 feet (maximum 120) from the release point in six hours, 42 at 120 feet (200) in 24 hours, and 16 at 280 feet (350) in 48 hours. In unfavorable conditions (wind above five miles per hour and temperatures below 60° or above 85° F.) the distances travelled for these times were respectively 25 feet (maximum 35), 40 (60), and 75 (110).

The insects are carried by the wind above five miles per hour but fly in any direction when it is less than five miles per hour. Those individuals that remain at low levels to avoid the wind disperse in any direction.

***Eulimneria rufifemur* (Thoms.)**

Descriptions of Immature Stages

Egg (Fig. 11).—Kidney-shaped, both ends rounded, one end slightly broader than the other; dorsal surface strongly convex and ventral surface distinctly concave. Chorion smooth throughout, uniformly brown, and sufficiently hard to retain its original shape after the larva emerges. Measurements of 10 eggs: length 0.40 mm. (range 0.38 to 0.55), greatest width 0.15 mm. (0.13 to 0.19).



Figs. 11-22. *E. rufifemur*. 11, Egg. 12-16, Larva. 12, First instar. 13, Second instar. 14, Third instar. 15, Fourth instar. 16, Fifth instar. 17-21, Right mandible of larva. 17, First instar. 18, Second instar. 19, Third instar. 20, Fourth instar. 21, Fifth instar. 22, Head capsule of fifth-instar larvae.

Larva.—Thorpe (1930) illustrated and briefly described the mature larva. Caudate in the first three instars (Figs. 12 to 14), changing gradually to hymenopteriform in the fourth and fifth (Figs. 15 and 16); white or yellowish; 13 body segments; antennae and setae not visible in any instar; nine pairs of spiracles and a silk duct visible in fifth instar only. The right mandible of each instar and the head capsule of the fifth instar are shown in Figs. 17 to 22.

Measurements for approximately 15 larvae reared on *P. interpunctella*:—first instar: length 0.97 mm., width 0.14 mm., width of head capsule 0.13 mm., ratio of length of tail to total length, 1:2; second: 1.40, 0.20, 0.18, 1:3; third: 1.91, 0.27, 0.25, 1:4; fourth: 3.72, 0.69, and 0.48; fifth: 5.38, 1.38, and 0.69. On the normal host, *R. buoliana*, whose larvae are much larger than those of *P. interpunctella*, the second to fifth instars of the parasite are usually larger than those on *P. interpunctella*.

Cocoon.—Size of 10 cocoons: length 6.5 mm., width 2.37 mm. Oval; light brown; densely spun; dark band reported by Thorpe (1930) absent in many of the specimens examined.

Life-History

E. rufifemur pupates in the spring in the mature larva or, less commonly, in the pupa. The cocoon is spun with the head of the pupa at the anterior end of

the host. Thorpe (1930) reported that, in England, the adults emerged from early in June to early in July and that females outnumbered males slightly. In the material imported from Belgium and reared at Belleville, 56 per cent were males.

Copulation usually occurs on the first day following the emergence of the female. Oviposition usually takes place about 12 days later. One or a few eggs are laid at a time. The oldest larva usually eliminates others in the same host early in the first instar, but occasionally two larvae persist to the second instar. This supports the theory (Clausen, 1940) that the oldest and strongest larva of many endoparasites is the survivor in instances of multiple parasitism.

In the spring the parasite larva grows slowly until the host larva matures. The parasite then develops more rapidly until the death of the host. The parasite spins its cocoon two or three weeks after the host dies. Additional details of the life history are given in Table I.

Behavior of Adult

Copulation.—The newly emerged females are the most attractive to the males, but copulation may occur with females four or five days old. Copulation is always preceded by a courtship of about two minutes' duration. The male begins by fanning the female by regular movements of his wings. Then, walking around the female or standing in front of her, he raises the anterior part of his body to the full height of his front legs. During this time, his antennae vibrate constantly and are extended towards the female. The male then touches the female with his antennae. If she moves away when touched, the male pursues her and prolongs the courtship until the female is ready. If the female does not move when touched, the male mounts her and copulates. The duration of copulation was 160 and 235 seconds in two instances. In the outdoor cage the male perceived the presence of the female as far away as five feet.

Oviposition.—The female is unresponsive to host larvae until mating has occurred. In the laboratory, *E. rufifemur* attacked either exposed or hidden host larvae. Only the larvae (of *R. buoliana*) still present inside the needles or wandering to the buds were attacked. In the outdoor cage a female about to oviposit searches for young larvae by probing with her ovipositor through the sheaths of all needles encountered within two to three inches of the bud.

Usually one egg is laid at each insertion of the ovipositor, but two eggs were found occasionally. A parasite may attack the same host more than once. As many as 15 eggs were found in one host larva. The eggs are usually deposited near the posterior end of the abdomen, but some were found in the thoracic region.

Females laid on the average 24 eggs each; one female laid 65 eggs in 18 days. Up to 75 eggs were counted in the ovaries of two females that had not laid.

Feeding.—In the laboratory, males and females fed readily on fresh raisins and honey in 10 per cent aqueous solution. They fed throughout the adult life. Females did not feed on the host larvae. In the outdoor cage, many males and females were seen feeding on the resin that often exudes from the apical halves of the needles. Once a female was seen feeding on the inflorescence of wild carrot, *Daucus carota* L. Males and females often drink dew from the undersides of pine needles in the early morning or after light rain.

Flight.—*E. rufifemur* flies within a relatively narrow range of temperature, wind velocity, and cloudiness. Flight begins when the temperature is about 65° F., reaches a peak about 80° F., and decreases rapidly above 85° F. However, the insect flies only during sunny intervals. The adults fly more when the

wind velocity is less than five miles per hour than at higher velocities. The normal daily variation in moisture has no discernible effect on flight.

The male and the female have similar flight habits. Under optimum conditions (65° to 85° F., wind of five miles per hour or less, sunny) flight is rapid, often changing in direction. In the dispersal flight, the parasite holds the body almost horizontal. In the mating or oviposition flights, the long axis of the body is at an angle of up to 20° to the horizontal. The tip of the abdomen of both male and female is sharply curved downward in flight. Under optimum conditions the parasite flies about the upper half of the tree, but under adverse conditions it ceases flying or is observed in protected places.

Rate and Pattern of Dispersal.—As mentioned above, the flight of *E. rufifemur* depends on temperature, wind velocity, and sunlight. Under optimum conditions, 43 recaptured specimens had dispersed an average of 40 feet (maximum 65) from the release point in six hours, and 23 at 70 feet (120) in 24 hours. Under unfavorable conditions, the distance covered for the above times were respectively 15 (30), and 30 (45).

The pattern of dispersal depends on the force and direction of the wind as well as on the size of the individual. Individuals of normal size are carried with wind above five miles per hour, but fly in any direction when the velocity is less than five miles per hour. Larger individuals were often seen flying directly into wind of almost eight miles per hour. When these larger parasites flew at a 20° angle or more to the direction of the wind, they were soon blown away, as with the normal-sized individuals. The individuals that remain at low levels and avoid the wind disperse in any direction.

Tetrastichus turionum (Htg.)

Descriptions of Immature Stages

Egg (Fig. 23).—Broadly oval with one end slightly wider than the other; ventral surface slightly concave and dorsal surface strongly convex; translucent white and uniformly smooth; chorion very soft; measurements of 10 eggs: length 0.34 mm. (range 0.32 to 0.38), greatest width 0.10 mm. (0.08 to 0.11).

Larva.—All four instars (Figs. 24 to 31) hymenopteriform; all with 13 body segments; first two instars usually white or yellowish, last two white, pink, or light brown; setae and antennae not visible in any instar; nine pairs of spiracles present in fourth instar only.

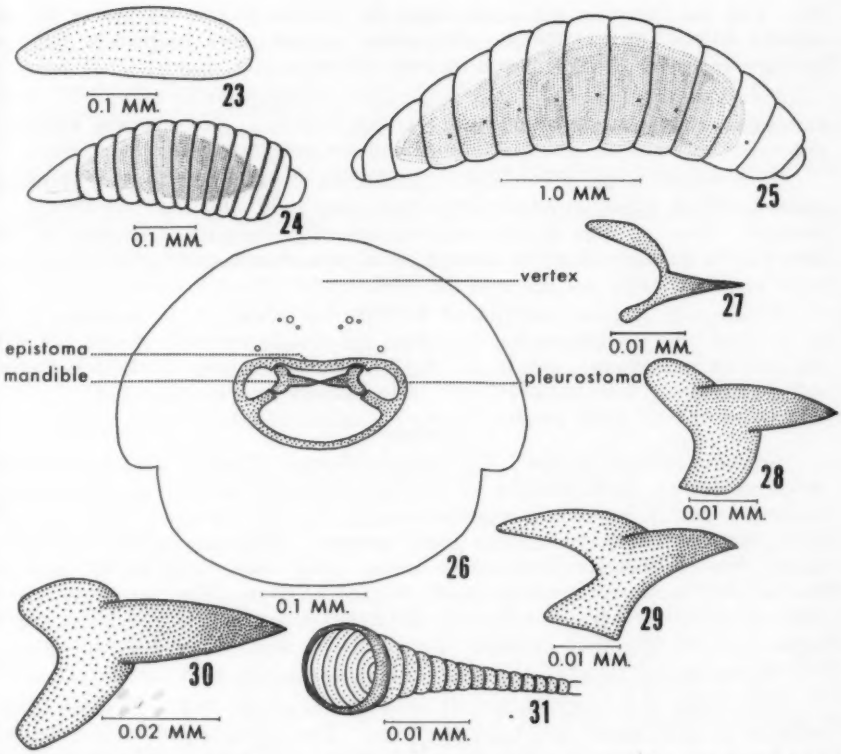
Measurements of the four instars, based on approximately 10 specimens each:— first: length 0.55 mm., width 0.15 mm., width of head capsule 0.06 mm.; second: 1.15, 0.31, 0.13; third: 2.04, 0.53, 0.27; fourth: 3.15, 0.97, 0.40.

Pupa.—Entirely white or yellowish; no cocoon.

Life-History

T. turionum pupates in the spring in the host and emerges when the host is in the pupal stage. Seven times as many females as males emerged from European material.

Copulation usually takes place before or immediately after the female escapes from the host. The first, second, and third larval instars last approximately one day each and the fourth instar almost a year. Though the fourth instar is the overwintering stage, adults were obtained on three occasions 19, 20, and 27 days after oviposition. The adult emerged from either the abdomen or the ventral part of the thorax of the pupa. On one occasion parasites emerged from a female moth. Additional details on the life history are given in Table I.



Figs. 23-31. *T. turionum*. 23, Egg. 24, First-instar larva. 25, Fourth-instar larva. 26, Head capsule of fourth-instar larva. 27-30, Right mandible of larva. 27, First instar. 28, Second instar. 29, Third instar. 30, Fourth instar. 31, Spiracle of fourth-instar larva.

Behavior of Adult

Copulation.—*T. turionum* mates more readily when the temperature is above 70° F. than when the temperature is below this point. Mating upon emergence is common, but it may occur at any time in the first three days. The male attempts to mate throughout the preoviposition period of the female, which usually mates only once.

Copulation is preceded by courtship lasting four to five minutes. The male mounts the dorsum of the female from one side, and vibrates his antennae against those of the female. This stops when the female ceases to move, and coitus is accomplished by the male bending the tip of his abdomen around the tip of the abdomen of the female. Coitus usually lasts 10 to 15 seconds but may be as long as 45 seconds.

Oviposition.—Oviposition was observed only in the laboratory. It is probably similar in the field except for the method employed by the female in searching the host pupa inside the bud cavity. In the laboratory the host pupae lie free on the bottom of the container and are easily accessible to the female. In the field the female must locate the host and work in the infested bud.

The host pupa does not respond to the mounting and movement of the parasite but often reacts violently to insertion of the ovipositor by turning and twist-

ing. This reaction does not occur when the parasite attacks the thorax or the anterior half of the abdomen. Oviposition occurs more frequently on the abdomen of freshly formed pupae than on old pupae.

Five females attacking 13 host pupae laid an average of 45 eggs each. The number of eggs per pupa averaged 17 (range 6 to 33). No apparent relationship exists between the size of the pupa and the number of eggs deposited.

T. turionum seems able to detect parasitized pupae. Females that attacked parasitized host pupae withdrew from them very soon after inserting their ovipositors. Two or three females were occasionally observed to oviposit in the same host at the same time, but as an exposed pupa does not occur in nature this habit would probably not occur in the field.

Feeding.—It was not determined whether the adults of *T. turionum* feed in the field. In the laboratory, the adults fed readily on fresh raisins, but did not feed on host pupae. Adults fed daily lived twice as long as those not provided with food.

Summary

Ephialtes ruficollis (Grav.), *Eulimneria rufifemur* (Thoms.), and *Tetrastichus turionum* (Htg.), three parasites of the European pine shoot moth, *Rhyacionia buoliana* (Schiff.), introduced into Canada from Europe, are respectively external larval, internal larval, and internal pupal parasites. They overwinter as mature larvae, first-instar larvae, and mature larvae. The males lived 26, 13, and 16 days in the laboratory; the females, 52, 27, and 27 days. The egg stages lasted 2-3, 3-4, and 2 days; the larval stages, 10-15, 310 ±, and 320 ± days; the pupal stages, 7-13, 20 ±, and 10 ± days. There are 5, 5, and 4 larval instars.

The immature stages of the three species are described.

The adults of *E. ruficollis* flew at temperatures of 60° to 85° F., flight being reduced in wind above five miles per hour. The adults usually mated in the first few hours after the female emerged. The average number of eggs deposited per female was 23, the reproductive potential being estimated at about 82 eggs. The females fed on the host larvae, reducing the amount of food available for the larvae; also, they fed avidly on pine resin. The average distance travelled in one day was 120 feet under favorable conditions and 40 feet under unfavorable conditions.

The adults of *E. rufifemur* flew at temperatures of 65° to 85° F., wind above five miles per hour reducing flight. The adults were not flying during cloudy intervals. Copulation usually occurred at emergence of the female. The average number of eggs laid per female was 24. The adults fed on pine resin and on the inflorescence of wild carrot. The average distance covered in one day was 70 feet under favorable conditions and 30 feet under unfavorable conditions.

The adults of *T. turionum* mated readily at temperatures above 70° F. Copulation occurred before or immediately after escape of the female from the host. Five females laid an average of 45 eggs each in 13 host pupae. Adults fed daily lived twice as long as unfed adults.

Acknowledgments

Many thanks are extended to Dr. H. E. Welch, Entomology Laboratory, Belleville, and Prof. A. H. MacAndrews, New York State College of Forestry, Syracuse, for helpful criticisms in the analysis of the data and writing of the manuscript. The assistance of Dr. A. P. Arthur in organizing the work was also greatly appreciated.

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(Received May 7, 1959)

Description and Habits of a New Species of *Phytophaga* (Diptera: Cecidomyiidae) from Western Red Cedar Cones[1]

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Introduction

Gall midges have been reported from cones of western red cedar, *Thuja plicata* Donn., but none have been described. Keen (1958) reported the occurrence in Washington and Oregon of a cone midge which was credited with destroying 90 per cent of the seed. In 1940 Prebble and Graham[2] reported a midge in cones of western red cedar at Cowichan Lake, B.C. These reports almost certainly refer to the midge described here. The only other species taken from red cedar cones was *Lestodiplosis taxiconis* Foote, but it occurred in very small numbers; previously it has been reported only from cones of Douglas fir, *Pseudotsuga menziesii* (Mirb.) Franco (Foote, 1956).

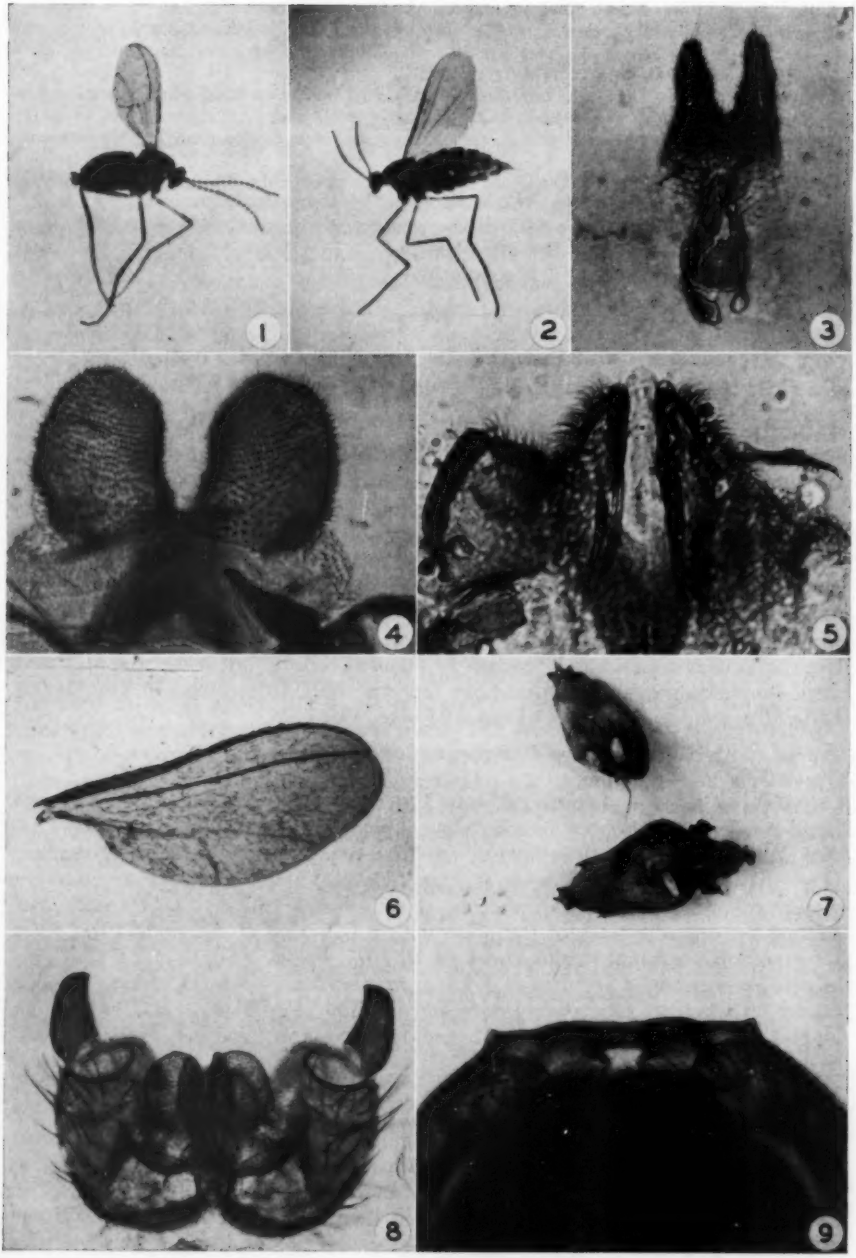
Phytophaga thujae n. sp.

Figs. 1-15

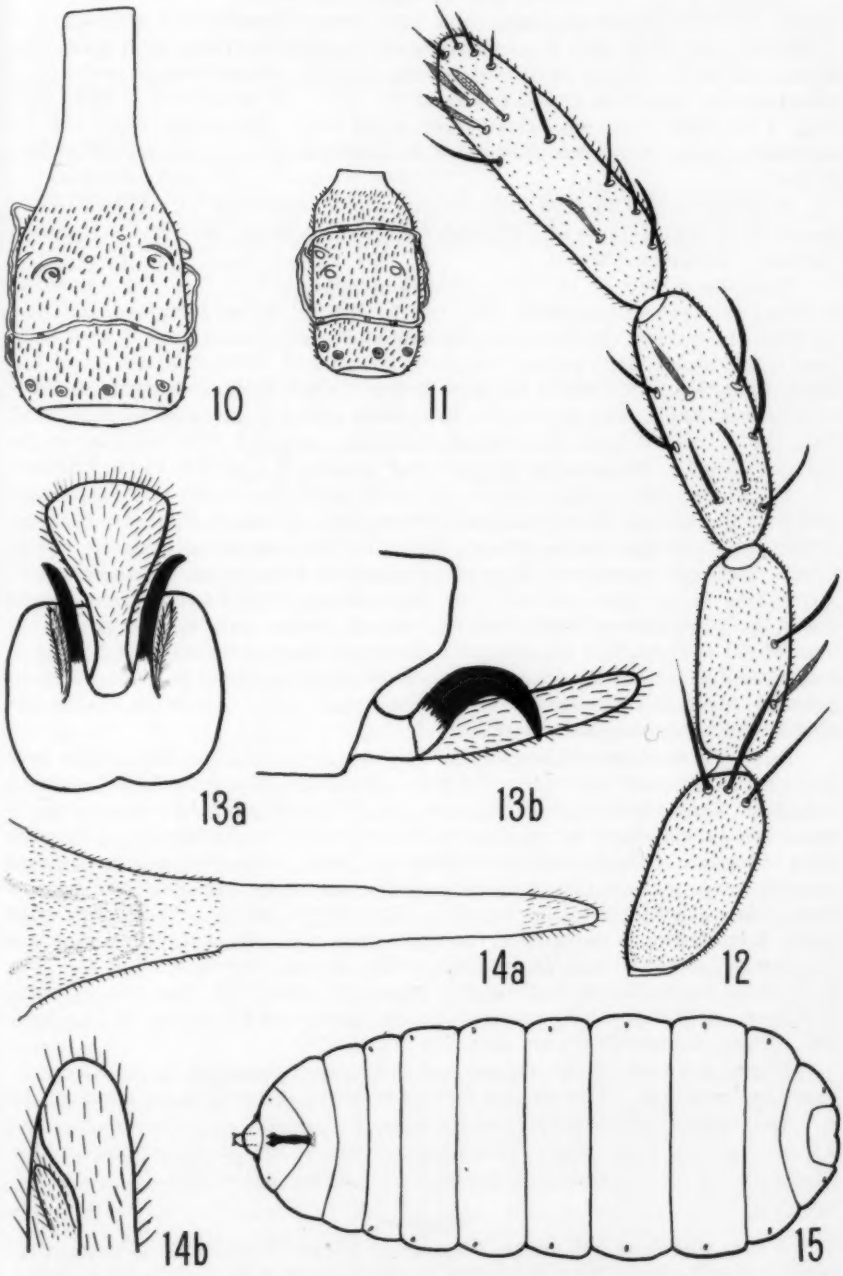
Male:—(Fig. 1). Length of body 2.44 (range, 18 specimens 1.92-2.84) mm. Head as wide as high from anterior view. Flagellum of antenna 1.98 (1.68-2.23) mm. long, with 17 to 19 segments, the first two fused; fifth flagellar segment (Fig. 10) with node 0.80 as wide as long, stem 0.75 as long as node, circumfilum closely adhering, consisting of one ring slightly below half way on the node connecting on opposite sides of the node with a half ring at the node apex; scape sub-triangular, greatest width equal to length. Palpus (Fig. 12) of four segments; proportions of segments 1:1:1.5:2; first segment 1.5 times as long as wide, remaining segments successively narrower. Wing (Fig. 6) 2.61 (2.31-2.88) mm. long, 1.12 (0.94-1.34) mm. wide; R_1 ending in costa at basal 0.4; R_5 bent gently at distal quarter to meet the costa slightly before the wing tip. Each leg covered with long narrow scales; proportions of hind tarsal segments 1:6.6:3.8:2.5:1.4; fore, mid, and hind claws (Fig. 13a, b) similar, simple and curved sharply; pulvillus about 0.5 length of claw; empodium (pulvillus of Felt, 1915 and probably of Foote, 1956) spatulate, longer than the claws. Terminalia (Fig. 8) wider than long, basistyle stout, length 2.0 times greatest width; dististyle has short stout tooth at apex; 10th tergite (Fig. 4) and 10th sternite (Fig. 3) about equal in length, both deeply emarginate; tergite is broad-lobed, lobes of sternite are bluntly pointed; aedeagus semitransparent, slightly longer than harpes (Fig. 5).

[1]Contribution No. 569, Forest Biology Division, Research Branch, Department of Agriculture, Ottawa, Canada.

[2]Unpublished data.



Figs. 1-9. *Phytophaga thujae* n.sp. 1. Male. 2. Female. 3. 10th sternite of male. 4. 10th tergite of male. 5. Harpes and aedeagus. 6. Wing. 7. Puparia (upper) and larva (lower) in cone. 8. Male terminalia. 9. Pupal antennal horns.



Figs. 10-15. *Phytophaga thujae* n.sp. 10. Fifth antennal segment of male. 11. Fifth antennal segment of female. 12. Palpus of male. 13a, b. Tarsal claw, empodium and pulvillus of male. 14a, b. Ovipositor. 15. Larva, last instar.

Female:—(Fig. 2). Head, palpus, scape and pedicel as in male. Body length 2.77 (range, 20 specimens 2.38-3.19) mm. Flagellum of antennae 1.25 (1.04-1.44) mm. long with 17 to 19 segments, the first two fused as in male; fifth flagellar segment (Fig. 11) 1.6 times as long as wide; circumfilum of two closely adhering rings joined on opposite sides of the node. Wing 2.76 (2.31-3.08) mm. long, 1.16 (1.03-1.31) mm. wide. Legs as in male. Ovipositor (Fig. 14a, b) retractile, ending in a simple lobe, with small pubescent node on ventral surface of lobe.

Holotype:— ♂, Langford, British Columbia, Canada, Jan. 23, 1958 (Hedlin), reared from larva in cone of *Thuja plicata* Donn., type no. 6831 in the Canadian National Collection, Ottawa.

Paratypes:—15 ♂ ♂, 14 ♀ ♀ same data as holotype, 5 ♂ ♂, 6 ♀ ♀, same data as holotype; 6 pupae, Langford, B.C., Jan. 7, 1958; 10 larvae, Langford, B.C. Jan. 15, 1958 (Hedlin) in the Canadian National Collection, Ottawa. 3 ♂ ♂, 3 ♀ ♀, same data as holotype; 7 pupae, Langford, B.C., Jan. 7, 1958; 6 larvae, Cowichan Lake, B.C., Aug. 28, 1958 (Hedlin) in the United States National Museum, Washington, D.C. 6 ♂ ♂, 6 ♀ ♀, same data as holotype; 4 pupae Langford, B.C., Jan. 7, 1958; 4 larvae Cowichan Lake, B.C. Aug. 22, 1958 (Hedlin) in the Barnes Collection, Rothamstead Experimental Station, Harpenden, Herts, England.

Discussion:—*Phytophaga thujae* runs to *P. americana* (Felt) or *P. destructor* (Say) in the key to North American *Phytophaga* given by Felt (1915); these species have *Salix* spp. and members of the family Gramineae respectively as their hosts. The only species of *Phytophaga* recorded from cones of conifers is *P. carpophaga* Tripp from cones of *Picea glauca* (Tripp, 1955) and of *P. engelmanii* and *P. sitchensis* (Foote, 1956); it differs from *P. thujae* in the male in having the stem of the fifth flagellar segment only about ½ as long as the node (¾ as long in *thujae*) and in having the lobes of tergite 10 much narrower and the notch of sternite 10 much shallower than in *thujae*, and in the female in having the flagellar segments completely sessile.

Biology:—*P. thujae* emerges early in the spring from puparia which have overwintered in cones on the tree. Adults were observed in the field at Cowichan Lake B.C., from March 12 to April 9 in 1958. They deposit their eggs in newly opened flowers. When the eggs hatch, the larvae feed on the surface of the scale tissue near the seeds but do not burrow or form galls; they remain exposed between cone scales. The early-instar larvae are white but gradually become more coloured until the final instar (Fig. 15) is bright orange. In August, when larval development is completed, the insect remains in the excavation which it has provided in the cone scale and spins a thin, delicate puparium (Fig. 7). The insect does not transform to the pupal stage until some time after the puparium is formed; in 1958 pupation occurred during January and February at Langford, B.C. Pupal antennal horns are shown in Fig. 9.

Ninety per cent of the western red cedar cones examined in 1958 were infested by the midge. The greatest number of larvae observed in one cone was 12.

Two species of hymenopterous parasites, *Torymus* n. sp. (Torymidae) and *Tetrastichus strobilus* Burks (Eulophidae) attack the larvae of the midge. Thirty-six per cent of the larvae in cones were parasitized in 1958.

Summary

A new species of gall midge, *Phytophaga thujae*, from cones of western red cedar is described and figured. Notes on the life history and habits are included. Another species of midge, previously recorded only from Douglas-fir cones, is noted.

Acknowledgments

The author wishes to thank J. R. Vockeroth, Entomology Research Institute, Ottawa, and R. R. Lejeune and D. Evans, Forest Biology Laboratory, Victoria, for their helpful criticism and advice. Photography was done by A. Craigmyle.

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(Received June 15, 1959)

A Field Cage for Rearing Syrphid Larvae and Other Predators of the Balsam Woolly Aphid, *Adelges piceae* (Ratz.) (Homoptera: Adelgidae)[1, 2]

By R. C. Clark[3] and N. R. Brown[4]

Several species of syrphids are common predators on the balsam woolly aphid, *Adelges piceae* (Ratz.), in eastern Canada. Larvae are found on infested trees throughout the summer in a certain sequence of species. Occasionally adult syrphids are collected while ovipositing.

Attempts have been made to rear the larvae in the laboratory on small pieces of infested bark but the difficulty of keeping the bark moist and preventing the growth of mould and of transferring the larvae to fresh bark made this method unsatisfactory. The prey died before rearing was complete. Rearing the larvae in the field appeared to be the solution to this problem and a suitable cage was designed which was simple to make, install, and examine (Fig. 1).

Four short pieces of wood 2 in. by 2 in. (Fig. 2A) were nailed at right angles to the trunk of an infested tree, in two pairs on opposite sides of the trunk. Vertical distance between the pairs of 2 in. by 2 in.'s was dependent on the width of plastic screening used. The top and bottom of the cage were made of ¾-in. plywood cut in two pieces to form a circle 18 in. in diameter fitting around the trunk of the tree (Fig. 2B). The top was nailed upward into the upper pair of 2 in. by 2 in.'s, the bottom downward into the lower pair. Two pieces of wood ¾ in. by 2 in. (Fig. 2C) were placed upright in recesses cut on opposite sides into the plywood top and bottom and nailed into place. The small spaces between the trunk and the plywood were packed with non-absorbent cotton batting.

Two pieces of plastic screening (Monofilament Saran, Style No. MS-900, National Filter Media Corporation, New Haven 14, Conn., U.S.A.) were cut long enough to extend slightly more than half way around the circumference of the cage (Fig. 2D). Beginning at the uprights, the screening was stapled to the top edge of the cage. Massive drawing pins were used to pin the vertical edges of the screening to the uprights and the lower edge to the bottom edge of the cage. It was thus very easy to remove the pins and lift the screening to examine

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[2]Joint project of Forest Biology Division, Research Branch, Department of Agriculture, Fredericton, N.B., and Department of Lands and Mines of New Brunswick, financed in part by funds from the Provincial Department.

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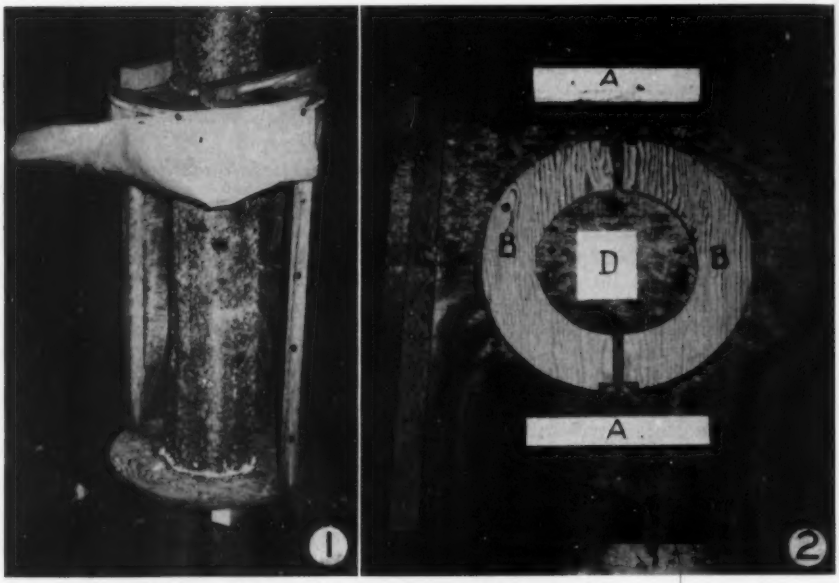

Fig. 1. Field rearing cage assembled around infested tree.
Fig. 2. Components of field rearing cage.

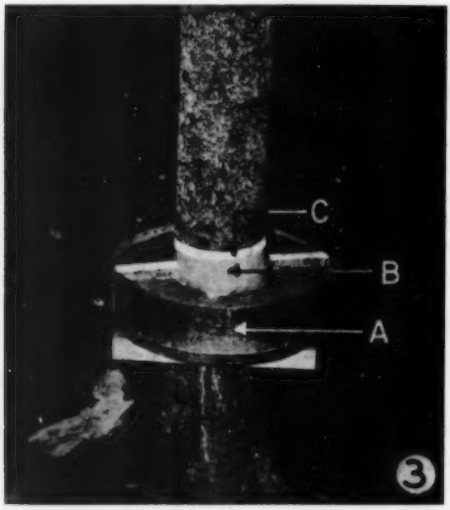

Fig. 3. Tray used on base of cage for species pupating in the soil.

the trunk surface or to open a small part along one of the uprights for the removal of newly-emerged adults from the cage.

As some of the syrphid species apparently pupated in the ground, trays with plywood bottoms and 3 in. high galvanized metal sides (Fig. 3A) were constructed. These were in two sections to fit around the trunk of the tree and

were placed on the bottom of the cage. Factory cotton attached with adhesive tape (Fig. 3B, C) was used to form a join between the trunk and the tray. Fine sifted, sterilized earth was placed in the trays and this was kept moist by occasional watering when necessary. Vermiculite, which retains moisture and does not crust, may be substituted for earth.

Before a cage was installed the trunk was examined and any predators found were removed. Larvae of one type were then placed on the bark in the cage. Using this method, adults from three types of syrphid larvae have been obtained and identified.

Other types of predators, notably hemerobiids and chrysopids, have also been reared in these cages with more success than was formerly obtained in the laboratory. Also, the cages have proved useful for the temporary caging of introduced predators. These have been retained in the cages for a few days in attempts to induce oviposition where the progeny may be reared and their habits studied.

Cages of this type are very resistant to weather. The plywood parts are bonded with a waterproof adhesive and the plastic screening does not rust, rot, or mildew. Several cages have been left in the field over winter with no ill effects other than the rusting of the wire staples.

(Received August 20, 1959)

Pyralidae Collected in Lower California by Mr. J. Powell (Lepidoptera)[1]

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I am indebted to Mr. J. Powell, University of California, Berkeley, for the privilege of studying a small but interesting collection of Pyralidae, made by him in the Sierra San Pedro Martir, Lower California, May 28 to June 3, 1958. As records from this region of Mexico are scarce, I take pleasure in publishing a list of the species.

Pyraustinae

Nomophila noctuella (Denis and Schiffermüller). Nine specimens: La Grulla, 6500 ft.; La Encantada, 7000 ft. Identical with North American specimens passing under this name.

Mecyna mustelinalis (Packard). A rather dark specimen, apparently referable to this species. La Encantada, 7000 ft.

Choristostigma zephyralis (Barnes and McDunnough), new combination. This species and its allies are not closely related to *Diasemia*, in which they have usually been placed in North American lists. Two large males, Las Encinas, 6000 ft.

Phlyctaenia terrealis (Treitschke). One male of the ochreous form that is common on the West Coast, La Gulla, 6500 ft.

Loxostege commixtalis cereralis (Zeller). Two specimens, La Gulla, 6500 ft.

Loxostege similalis (Guenée). A somewhat rubbed female, apparently identical with specimens from the Central U.S.A., one mile east of Meling Ranch, 2000 ft.

[1]Contribution No. 3914, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada.

Figs. 1-3. 1, *Pyrausta tatalis* (Grote), five miles northeast of La Encantada, 9000 ft.; 2, *Gyros powelli* Munroe; 3, *Gyros muiri* Hy. Edwards.

Pyrausta futilalis inconcinnalis (Lederer), new status. This bright-ochreous form seems to be only the western subspecies of *P. futilalis*. Two specimens, La Encantada, 7000 ft.

Pyrausta perrubralis (Packard). A badly rubbed specimen, with the dark markings apparently more restricted than in topotypical material. Las Encinas, 6000 ft.

Pyrausta tatalis (Grote). A very brightly marked female (Fig. 1), probably belonging to this species, but much more contrastingly marked than any in a series of 24 specimens from several southwestern states of the U.S.A. Five miles northeast of La Encantada, 9000 ft. More material of this form is needed for exact placement.

Odontiinae

Gyros powelli, new species (Figs. 2, 4). Structure and facies as in *G. muiri* Hy. Edwards. Head and palpi roughly scaled, creamy buff, with considerable admixture of black scales and hairs; thorax and base of abdomen above black with considerable creamy-buff scaling; distal part of abdomen orange-buff; body beneath and legs largely creamy buff. Forewing with costa almost straight, outer margin broadly rounded; hind wing rounded. Forewing above light buff, suffused to a varying degree with red and overlaid with diaphanous white scales; basal area suffused with deep vinous red or purplish fuscous, lightly overlaid with white scales; limit of basal area oblique, extending from costa at one-third to inner margin beyond middle; an oval, blackish-fuscous discocellular spot, surrounded by intensified red scaling; postmedial line blackish fuscous, interrupted or obsolescent, close to and almost parallel to outer margin; terminal line

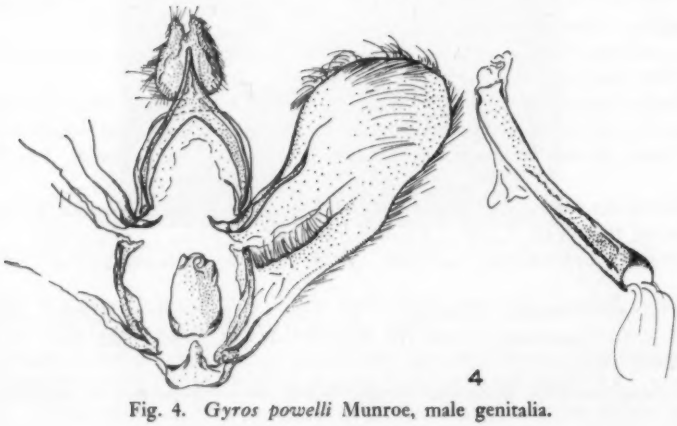

Fig. 4. *Gyros powelli* Munroe, male genitalia.

blackish fuscous; fringe fuscous, darker in basal half, whitish buff at extreme outer edge. Hind wing brick red, terminal line and fringe as on forewing. Fore and hind wings beneath yellowish buff, with some reddish suffusion at base and along costa; terminal line and fringe as above. Expanse 10-13 mm.

Male genitalia. Closely similar to those of *G. muiri*, valve probably somewhat narrower.

Holotype, male, allotype, female, and 28 paratypes, La Grulla, 6500 ft. Holotype, allotype and a series of paratypes in the California Academy of Sciences, San Francisco; a series of paratypes in collection of University of California, Berkeley; a series of paratypes in C.N.C., type no. 6819.

This species is closely related to *G. muiri*, and might be considered only a subspecies; however, the much more restricted basal patch, with its differently shaped outer border, seems to suggest specific status. The average size is smaller in the present species, the ground colour of the forewing is much more pallid, and that of the hind wing is lighter red. The differences in genitalia are perhaps not significant, but large genitalic differences between related species are not necessarily to be expected in this subfamily. The nearest locality from which I have seen *G. muiri* is Alma, Calif.

Summary

Ten species of Pyralidae are recorded from the Sierra San Pedro Martir, Lower California, including *Gyros powelli*, new species. *Diasemia zephyralis* Barnes and McDunnough is transferred to *Choristostigma*, and *Pyrausta inconcinnalis* (Lederer) is reduced to a subspecies of *P. futilalis* (Lederer).

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Hymenoptera Reared from the Mossy Rose Gall Caused by *Diplolepis rosae* (L.) (Hymenoptera: Cynipidae)

By W. W. Judd
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On January 10, 1958 a collection of 20 galls was made from a rose bush in an abandoned brickyard bounded by Cheapside, Taylor, Victoria and Adelaide Streets at London, Ontario. This was the same site in which collections of galls were made from goldenrod and willow by Judd (1953, 1958). Collections of flowers and leaves from the rose bush were made later in the year on June 20 and fruits were collected on September 14. From examination of these the bush was identified as *Rosa canina* L. by Dr. F. H. Montgomery, Department of Botany, Ontario Agricultural College, Guelph, who retained specimens of the plant for the herbarium of that institution. Specimens are also retained in the writer's herbarium (sheets 603, 604). By using keys in Felt (1940) the galls were identified as mossy rose galls or rose bedeguars caused by the cynipid wasp *Diplolepis rosae* (L.). The galls were roughly oval and were clothed with a furry covering of flexible filaments, thus resembling galls of this species figured by Connold (1902) and Felt (1940). The 20 galls ranged in size from 1¼ in. x 1¼ in. to 3 in. x 2½ in. Connold (1902) records the average dimensions of a mature gall to be 35 mm. and Felt (1940) reports diameters up to four inches. Callan (1944), Connold (1902) and Muesebeck *et al.* (1951) report that this gall has been introduced from Europe into North America and occurs habitually on the dog-rose, *Rosa canina* L., a shrub which itself has been introduced into North America from Europe (Fernald, 1950).

Each of the 20 galls was placed in a separate, numbered jar plugged with cotton and the jars were kept in a laboratory at room temperature and were examined daily for the presence of insects which emerged from the galls. These insects were removed from the jars and pinned or preserved in fluid and labelled to show the date of each insect's emergence and the number of the gall from which it emerged. The galls were discarded on December 31. All the insects are deposited in the collection of the Department of Zoology of the University of Western Ontario except some retained in the Canadian National Collection (CNC), as noted in the following account. The periods of emergence of the insects are shown in Fig. 1 and the numbers that emerged from each gall are shown in Table I.

Altogether 713 wasps emerged from the galls, these being *Diplolepis rosae* (L.), *Orthopelma mediator* (Thunb.), *Torymus bedeguaris* (Linn.) and *Habrocytus bedeguaris* (Thomson). No galls yielded all these species but several yielded three of them (Table I). The greatest number of insects reared from one gall, 79, came from gall No. 14 which was one of the largest of the galls.

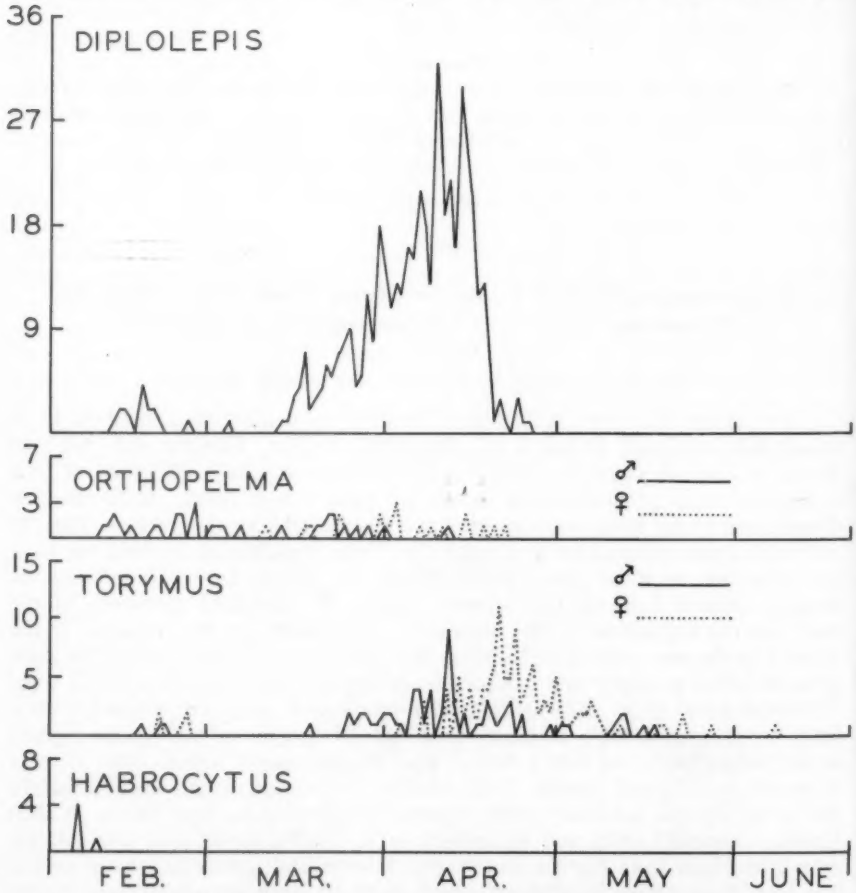

Fig. 1. Periods of emergence of wasps reared from mossy rose galls.

TABLE I.
Numbers of wasps from 20 galls.

Insects	Sex	Gall Numbers																				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	All
Diplolepis rosae	♀	60	48	9	4	34	36	48	21	7	16	16	22	8	42	7	10	18	28	6	25	465
Orthopelma mediator	♂					13								1	18					0		32
	♀					3								2	16					2		23
	All					16								3	34					2		55
Torymus bedeguaris	♂	7	7	4	1	1	11	2	0	1	4	10	6	0	2	3	2	6	2	1	3	73
	♀	7	13	4	4	3	4	10	2	8	6	6	8	0	1	8	4	3	7	9	8	115
	All	14	20	8	5	4	15	12	2	9	10	16	14	0	3	11	6	9	9	10	11	188
Habrocytus bedeguaris	♂	2	0				1															3
	♀	1	1				0															2
	All	3	1				1															5
Totals		77	69	17	9	54	52	60	23	16	26	32	36	11	79	18	16	27	37	18	36	713

The greatest number of the species which causes the gall, *Diplolepis rosae*, from one gall was 60 (gall No. 1). Connold (1902) records that the numbers of cells in a gall range from 30 to 50.

Cynipidae

Diplolepis rosae (L.)

From February 12 to April 25 there emerged 465 wasps of this species (Table I). The maximum number to emerge in one day was 32 on April 9 (Fig. 1). All the wasps were females. They were identified as *D. rosae* by Miss Lois K. Smith, Insect Systematics and Biological Control, Department of Agriculture, Ottawa, who retained five specimens for the CNC.

D. rosae emerged from all 20 of the galls collected. It is recorded as the insect that causes the gall by Connold (1902), Felt (1940) and Muesebeck *et al.* (1951). Ontario is included in its range in North America by Muesebeck *et al.* (1951).

Ichneumonidae

Orthopelma mediator (Thunb.)

From February 10 to April 21 there emerged 55 wasps (32 ♂ ♂, 23 ♀ ♀) of this species (Table I). The maximum number that emerged in one day was three, on February 26 and April 2 (Fig. 1). Males emerged first on February 10, reached their maximum emergence per day on February 26 and emerged last on April 11. Females emerged first on March 10, reached their maximum emergence per day on April 2 and emerged last on April 21. The wasps were identified as *O. mediator* by Mr. G. S. Walley, Insect Systematics and Biological Control, Department of Agriculture, Ottawa.

O. mediator emerged from four of the galls collected. It is recorded as a parasite of *D. rosae* by Muesebeck *et al.* (1951) and Thompson (1950). Connold (1902), including it under the name *Hemiteles luteolator*, also records it as a parasite of *D. rosae*. It is recorded from Ontario by Muesebeck *et al.* (1951).

Torymidae

Torymus bedeguaris (Linn.)

From February 17 to June 7 there emerged 188 (73 ♂ ♂, 115 ♀ ♀) wasps of this species (Table I). The maximum number that emerged on one day was 13,

on April 11 (Fig. 1). Males emerged first on February 17, reached their maximum emergence per day on April 11 (9 wasps) and emerged last on May 17. Females emerged first on February 20, reached their maximum emergence per day on April 20 (11 wasps) and emerged last on June 7. The wasps were identified as *T. bedeguaris* by Dr. O. Peck, Insect Systematics and Biological Control, Department of Agriculture, Ottawa, who retained three males and four females for the CNC.

T. bedeguaris emerged from 19 of the galls collected. The classification of this species has been clarified by Hobbs (1948). It is recorded as a parasite of *D. rosae* by Connold (1902) and Muesebeck *et al.* (1951). Thompson (1950), including it under the name *Callimome bedeguaris*, also records it as a parasite of *D. rosae*. Muesebeck *et al.* (1951) record one North American record of this species, a doubtful one from Colorado.

Pteromalidae

Habrocytus bedeguaris (Thomson)

Three males and one female of this species emerged on February 6 and one female emerged on February 9 (Fig. 1). The wasps were identified by Dr. Peck who retained two males and one female for the CNC.

H. bedeguaris emerged from three of the galls collected (Table I). It is recorded as a parasite of *D. rosae* by Callan (1944) and Muesebeck *et al.* (1951). Thompson (1950) records it as a parasite of both *D. rosae* and *O. mediator*. The three galls from which this wasp emerged yielded *D. rosae* but not *O. mediator* (Table I). Muesebeck *et al.* (1951) record this species from Ontario.

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(Received February 24, 1959)

Abdominal Characters of *Dioryctria* Pupae (Lepidoptera: Pyralidae) from British Columbia[1]

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The following is an illustrated discussion of pupal abdominal characters observed in British Columbia species of *Dioryctria*, a genus containing some of the most economically important cone-feeding and wood-boring Lepidoptera. Species examined and referred to herein are: *cambiicola* (Dyar), *zimmermani* (Grote), *abietivorella* (Grote), *auranticella* (Grote), *rossi* Munroe, *reniculella* (Grote), and *pseudotsugella* Munroe. *Dioryctria reniculella* and *pseudotsugella* are defoliators, but they may occasionally feed on cones.

Only the abdominal segments are considered in this paper since head and thoracic features were lost or damaged in most of the available pupal cases.

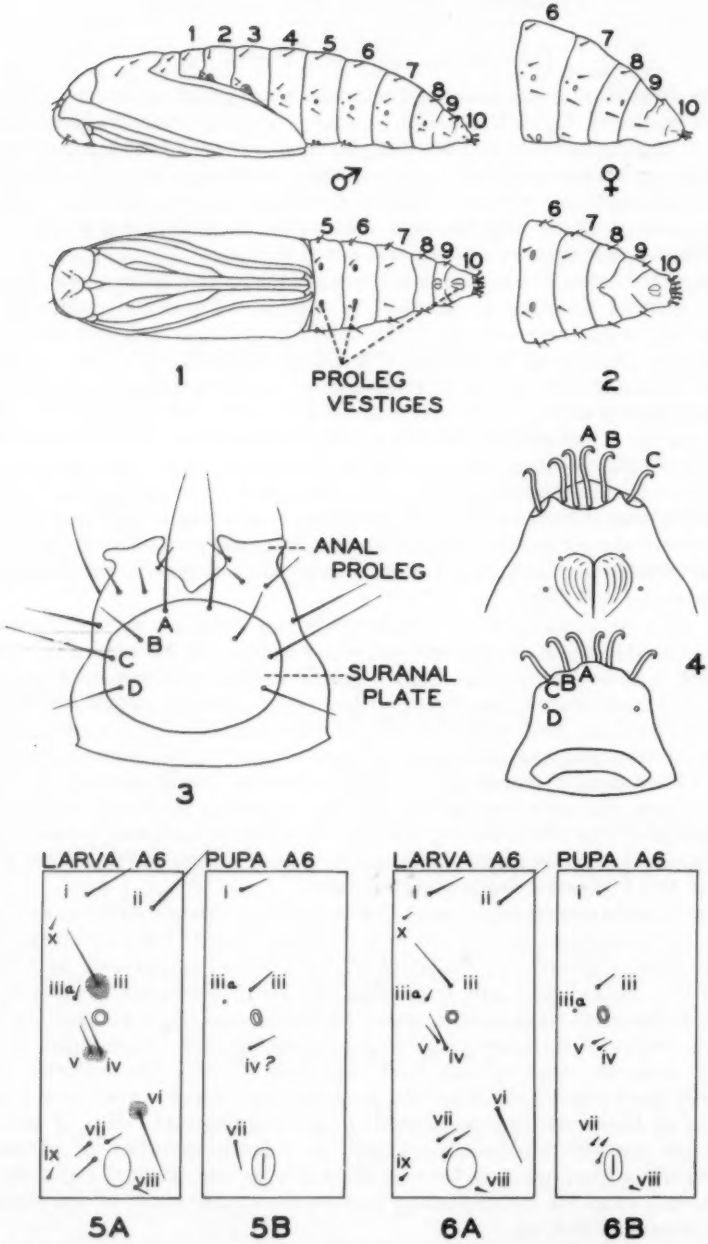
The abdominal segments are fairly distinct, although it is not always easy to determine boundaries of the fused terminal segments. The first abdominal spiracle is absent; the eighth is rudimentary and nonfunctional in the pupa although larger than the other abdominal spiracles in the larva. The position of the prolegs is prominently indicated by wrinkles (Fig. 1). Vestiges of the ventral and anal prolegs are apparent in the pupal stage, although they are normally in an invaginated position when the ultimate larval exuviae have been shed. The anus is between the vestiges of the anal prolegs. The pupal genitalia are similar to those that have been illustrated frequently in other highly evolved Frenatae; the female genital pores are on segments 8 and 9, the male genital pore on segment 9 (Figs. 1 and 2).

So far I have not seen any reference in the literature to setal homologies between lepidopterous larvae and pupae, therefore an attempt was made to determine homologies by their relative position. An examination of pupae and larvae of *Choristoneura fumiferana* (Clem.) and *Barbara colfaxiana* Kft. disclosed the fact that both stages of each of these species have precisely the same number of setae and the same setal pattern, at least on the ventral proleg segments. Therefore, if homologies between setae may be determined by relative position alone, the same terminology may be employed for larvae and pupae. I have accepted this relativety of position of setae as adequate proof that the homologies are true, and henceforth in this paper will use nomenclature devised by Dyar and Forbes for lepidopterous larvae.

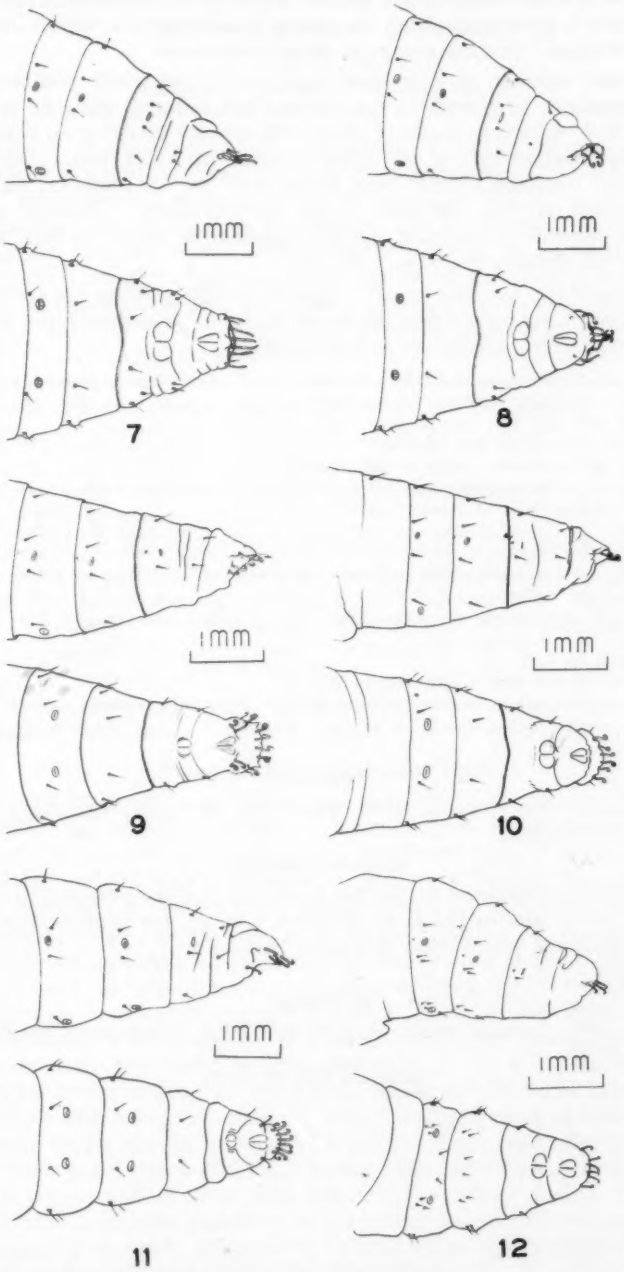
The chaetotaxy of the pupae of *Dioryctria* is complicated by the loss of setae in the transition from the larval to the pupal stage. No noteworthy differences have been observed in the larval setal patterns of *auranticella, abietivorella,* (e.g., Figs. 5A and 6A) and *reniculella,* the only *Dioryctria* larvae that were examined minutely; however the pupa of *abietivorella* (Figs. 6B and 12) differs from the pupae of all other local species in having two subspiracular setae (*iv* and *v*) whereas other species have one only (*iv*?). The anterior, microscopically small setae *ix* and *x* and the posterior setae *ii* and *vi* are absent from the pupae of all *Dioryctria* spp. mentioned in the foregoing text. Setae *ii* and *vi* occurred on the fifth abdominal segment in a freak specimen of *auranticella.* Occasionally a specimen may have an extra seta on one or more segments, however in such cases the corresponding seta on the opposite half of the segment is almost invariably lacking.

The following generalizations refer to segments 4 to 7, only, of the pupa. Seta *v* is absent from all species excepting *abietivorella.* Seta *iii*a has been lost,

[1]Contribution No. 559, Division of Forest Biology, Research Branch, Department of Agriculture, Ottawa.



Figs. 1-6, *Dioryctria* spp. 1-4, *D. auranticella.* 1, lateral and ventral aspects of male pupa; 2, female pupa; 3, dorsal caudal aspect of larva; 4, ventral and dorsal aspect of end of pupal abdomen; 5, *D. auranticella;* 6, *D. abietivorella.*



Figs. 7-12. Lateral and dorsal aspects of caudal portion of pupal abdomen of *Dioryctria* spp. 7, *D. cambiicola;* 8, *D. zimmermani;* 9, *D. reniculella;* 10, *D. pseudotsugella;* 11, *D. rossi;* 12, *D. abietivorella.*

although in at least some of the species its position is indicated by a "bud". Only one seta is present in group *vii*, except in *abietivorella*, which has three, as in the larval stage. Seta *viii* occurs in *abietivorella* only.

A greater number of setae have been lost in the much contracted, fused terminal segments, 8, 9, and 10, the number lost differing between sexes. The pupal terminal "spines" or hooks of *Dioryctria* spp. are homologous with the setae near the posterior margin of the larval suranal plate (see Figs. 3 and 4 of *D. auranticella*). Interspecifically these hooks may vary in number; also there is some difference in their thickness, shape, and curvature. Terminal hooks and the general shape of the terminal segment appear to be similar in male and female pupae (e.g. *D. auranticella*, Figs. 1 and 2).

The following is a key to the pupae of conifer-feeding *Dioryctria* spp. in interior British Columbia, (male pupae illustrated). It demonstrates some noteworthy interspecific differences in the genus.

1. Setae *iv* and *v* present on abdominal segments 4 to 7; three setae in group *vii* on segments 5 and 6 (6 slender hooked terminal spines) ..... (Fig. 12) *abietivorella*
   Seta *v* absent; only one seta in group *vii* 2
2. Terminal spines thick, not twisted 3
   Terminal spines slender, some or all twisted 6
3. Two hooked setae on either side of the anus; lateral posterior edges of terminal segment pointed; ends of spines "corkscrewed" ..... (Fig. 9) *reniculella*
   Fewer than two hooked setae on either side of the anus; edge of terminal segment rounded laterally 4
4. Caudal edge of terminal segment scalloped; tip of each spine forming an almost complete coil; foliage feeder ..... (Fig. 10) *pseudotsugella*
   Caudal edge of terminal segment entire; tips of spines less strongly hooked; cone feeders 5
5. Six terminal hooks ..... (Fig. 1) *auranticella*
   More than six terminal hooks, usually 8 ..... (Fig. 11) *rossi*
6. Ends of terminal spines, usually 8, almost straight or slightly hooked ..... (Fig. 7) *cambiicola*
   Ends of terminal spines, usually 6, strongly hooked ..... (Fig. 8) *zimmermani*

Summary

Abdominal characters of seven species of *Dioryctria* occurring in British Columbia are described.

Acknowledgments

The writer is indebted to Mr. B. A. Sugden for the preparation of Figures 1, 2, and 7 to 12, and to Dr. E. G. Munroe, Ottawa, for identification of adults associated with the pupal cases that were studied.

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Hibernation Sites of Phytoseiids (Acarina: Phytoseiidae) in Ontario Peach Orchards

By WM. L. PUTMAN
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Canada Department of Agriculture, Vineland Station, Ontario

A number of authors who have mentioned phytoseiid mites as predators of tetranychids reported that "*Seius*" or "*Seiulus*" spp. hibernated in the bark of trees, but until recently the taxonomy of the Phytoseiidae was so confused that the identity of the species concerned is uncertain. Herbert (1952), in Nova Scotia, was apparently the first to deal with species that can be definitely identified; she reported that a number of species of *Typhlodromus*, including most of those occurring on peach in Ontario, overwintered on apple trees under bark scales, in empty hibernacula of the eye-spotted bud moth, *Spilonota ocellana* (D. & S.), in empty oyster-shell scales, *Lepidosaphes ulmi* (L.), and in cocoons of the codling moth, *Carpocapsa pomonella* (L.). Chant (1958) found numbers of *T. pyri* Scheut. hibernating in burlap pads tied to apple trees in England.

This paper reports some observations on the hibernation sites of phytoseiids made during a study of predacious arthropods in peach orchards of the Niagara Peninsula, Ontario. Later papers will cover other phases of their biology and their importance as predators.

The species found hibernating in the orchards were *Typhlodromus* (*T.*) *rhenanus* (Oudms.), T. (*T.*) *pyri* Scheuten (= *tiliae* Oudms.), *T.* (*A.*) *fallacis* (Garm.), *T.* (*A.*) *finlandicus* (Oudms.), *T.* (*T.*) *longipilus* Nesbitt, *T.* (*T.*) *conspicuus* (Garm.), *T.* (*A.*) *cucumeris* (Oudms.), *T.* (*A.*) *andersoni* Chant, and *T.* (*A.*) *guatemalensis* Chant. Thanks are due to Dr. H. H. J. Nesbitt, Carleton University, Ottawa, and Dr. D. A. Chant, Entomology Research Institute for Biological Control, Research Branch, Canada Department of Agriculture, Belleville, Ont., for their identification.

Potential Sites on Peach Trees

Although the bark of the trunks and older limbs of mature peach trees is superficially rough it has relatively few deep crevices or loose scales that offer shelter like that beneath the bark scales of apple and many other trees. As the thin outer layer of the bark is ruptured by growth of the tree the fragments curl outward, often into small light curls, but are eventually shed from older wood.

Perennial cankers, which arise from fungal infection of wounds (Willison, 1932, 1936), are common on the branches and trunks of most peach trees in Ontario orchards and afford many potential hibernation sites. A canker is typically an elongate necrotic area of any size up to many square inches; older ones contain concentric overlapping layers of dead callus, often penetrated by borings of the lesser peach tree borer, *Synanthedon pictipes* (G. & R.), and surrounded by a variable extent of dead or dying bark, which develops internal cavities and separates from the wood as it dries. Various boring species of Coleoptera may subsequently invade the dying bark. An active canker, especially when infested with the lesser peach tree borer, also contains quantities of gum, which is fluid or gelatinous when fresh or after rains but which solidifies during dry weather. Frass of larvae of the lesser peach tree borer is often mixed with the gum. Cocoons of the oriental fruit moth, *Grapholitha molesta* (Busck), are frequently spun in crevices of cankers and may persist for several years.

Scale insects belonging to the genus *Lecanium* have been common and often injurious in Niagara district peach orchards in recent years. Mr. J. H. H. Phillips

(unpublished) of the Vineland Station laboratory has found that they constitute a complex of species whose identity is uncertain. After the eggs hatch in early summer, many of the dead females remain attached to the twigs and smaller branches through the following and sometimes the second winter. Beneath the scale body is a large cavity partly filled with egg shells and dead young that failed to escape. Scales parasitized by *Pachyneuron altiscutum* (How.) also contain small blister-like cavities.

Methods

Examination of Natural Sites.—The studies were carried on from 1952 to 1958 in peach orchards 12 or more years old owned by Messrs. G. Janzen, St. Catharines; W. D. Troup, Jordan Station; and the Ontario Horticultural Experiment Station (Victoria and Boothman orchards), Vineland Station, all in Lincoln County. The plots in the Victoria and Boothman orchards had not received any sprays for two or more years; those in the Janzen and Troup orchards had received only captan.

Pieces of cankered limbs, mostly one-half to two in. in diameter, were collected at pruning time in late winter. Cankers from scaffold limbs up to four in. in diameter, and pieces of living and dead bark from the trunks, were collected when the trees in the Boothman orchard was removed in the winter of 1954-55. Any material not examined by the middle of March was stored in the refrigerator at 38-40°F. All of the earlier material, and much of the later, was carefully dissected with knives and needles under a stereoscopic microscope; as examination of a large canker required several hours the number of samples was limited. Extraction of the mites in Berlese funnels was successful if the funnels were carefully operated; phytoseiids do not respond readily to a humidity gradient but require relatively high radiant heat to drive them down in the funnels. After many trials the following method was devised:

Rings of petroleum jelly were placed just inside the upper edge of the funnel and about the outside of the lower end of the spout. A vessel of 70 per cent alcohol was placed under the spout. The piece of bark or limb was put on a screen set one inch below the top of the funnel and left for 24 hours at room temperature to allow the mites to arouse from dormancy. An infrared lamp was then placed about 18 inches above the funnel and a piece of paper was laid over the bark or limb to protect it from direct radiation. After another 24 hours most of the mites had congregated on the lower part of the piece being extracted and on the walls of the funnel. The paper was then removed and the lamp lowered to provide stronger heat for another 24 hours to drive them down into the alcohol. At the end of this period any dead mites were brushed down from the inside of the funnel and the spout was examined for any that were stuck in the petroleum jelly. Examination of a number of cankered limbs after extraction in this manner showed that the great majority of the phytoseiids had been removed.

A half-inch layer of surface soil and litter was extracted similarly. Some of the mites were not recovered if a thicker layer was placed in the funnels.

Twigs bearing old *Lecanium* scales were collected from the trees in January or from prunings in March, and the contents of the scales examined under a stereoscopic microscope.

In two orchards a sparse ground cover of chickweed, *Stellaria media* (L.) Cyrillo, was examined in the spring by agitating tufts of the weed in a vessel of 70 per cent alcohol and allowing the mites to sink to the bottom. Most of the alcohol was decanted and the residue was washed into a beaker. This was repeated once or twice until the residue was concentrated to about 10 ml. in a small beaker.

A concentrated solution of calcium chloride was pipetted beneath the alcohol and the mites were picked out with a pipette as they floated at the interface between the two solutions.

From 75 to 95 per cent of the total numbers of the phytoseiids found in different lots of material were preserved in alcohol and later mounted in Hoyer's medium for identification.

Experiment with Cocoons of the Oriental Fruit Moth.—As will be shown later, hibernating phytoseiids were very commonly found in empty lepidopterous cocoons, and an experiment was accordingly set up to determine whether the cocoons exerted some specific attraction. Larvae of the oriental fruit moth were allowed to spin cocoons within strips of corrugated cardboard and to emerge as moths. Small pieces about three by 10 mm. and bearing the adherent wall of a cocoon were cut out of the cardboard and similar pieces were cut from cardboard that did not contain cocoons. The pieces were glued 12 mm. apart on strips of cloth, those bearing cocoons alternating with those that did not. On September 24, 1956, the strips were wrapped, with the cardboard strips outward, about small, smooth-barked limbs in the Boothman orchard and outer wrappings of burlap put over them. In late December the strips were removed and the numbers of living mites in contact with each strip were recorded.

Limbs and Trunks.—All of the cankers collected in 1953-54 and 1954-55 were dissected. About half of the cankers collected in 1955-56, and of the bark samples in both winters, were dissected and the rest were extracted in Berlese funnels; there were no consistent differences in the numbers of mites recovered by the two methods. In the dissections only apparently living mites were recorded; some error may have been introduced because part of those considered dead may have been only torpid.

Results are given in Table I. Among any lot of samples the mite population varied greatly from sample to sample, particularly among cankers, with little correlation between the area or other characteristics of the canker and the number of mites it contained. In the collection from the Boothman orchard in 1955-56, a canker with an area of 2.5 sq. in. yielded 750 mites whereas several other cankers with areas as great as 17 sq. in. did not yield any. Cankers that had killed the limb beyond the diseased area contained about as many mites as those on living limbs, and some cankers on entirely dead limbs also contained numbers of mites.

In the cankers the phytoseiids were usually in deeper crevices formed by shrinkage of dead wood and bark or in old tunnels of the lesser peach tree borer. Some were found just beneath the thin outer bark but they had entered through deeper crevices and light could not reach the site. Empty cocoons of the oriental fruit moth, the lesser peach tree borer, and chrysopids were especially favoured sites which often contained most of the mites found in a canker. When larger cavities were occupied the mites were usually packed into one end or into smaller lateral crevices. In lepidopterous cocoons they were often packed within the larval or pupal exuviae or in dried dead pupae. Very few mites were found in wet, gummy parts of cankers, but a few were found still alive but with their legs stuck in the dried, varnish-like gum. The relative scarcity of the mites in the Boothman samples of 1956-57 may have been due to the unusually gummy condition of many of the cankers. None were found among the frass, mixed with gum, of the lesser peach tree borer, or in occupied tunnels of the borer.

A striking characteristic of hibernating phytoseiids was their occurrence in aggregations. Among the multiplicity of apparently similar sites in a larger

TABLE I
Numbers of *Typhlodromus* spp. recovered from limbs and trunks of peach trees, Lincoln County, Ontario, 1953-1957.

Winter and orchard	Material	Number of samples	Total area, sq. in.	Number with mites	Number of each species
1953-54					
Victoria	Limb cankers	17	—	11	199 *rhenanus* 13 *pyri* 1 *finlandicus*
1954-55					
Victoria	Limb cankers	25	262	20	759 *rhenanus* 25 *pyri* 18 *finlandicus* 5 *andersoni*
	Trunks, living bark	35	292	13	25 *pyri* 2 *cucumeris* 1 *fallacis* 1 *andersoni*
	Trunks, dead bark	31	222	13	17 *pyri* 76 *cucumeris*[1] 4 *andersoni*
1955-56					
Janzen	Limb cankers	27	141	18	737 *rhenanus*[2]
	Trunks, dead bark	14	131	4	1 *rhenanus* 3 *fallacis*
Boothman	Limb cankers	23	100	18	1,777 *rhenanus* 14 *pyri* 1 *fallacis* 7 *andersoni*
1956-57					
Boothman	Limb cankers	30	256	22	294 *rhenanus* 47 *pyri* 2 *fallacis* 1 *longipilus* 11 *conspicuus*
Troup	Limb cankers	12	80	8	42 *rhenanus* 1 *fallacis* 6 *conspicuus* 67 *guatemalensis*

[1]35 from one sample
[2]217 under one dead *Lecanium* scale

canker, the mites were always concentrated in relatively few. For example, in the collection from the Victoria orchard in 1954-55, a canker with an area of 9 sq. in. contained aggregations of 8, 5, 7, 29, 8, 9, and 75 mites; among a total of 759 mites found in this collection the average number per aggregation was 13 and only 12 were solitary individuals.

The foregoing applied especially to *T. rhenanus*, by far the commonest species, but as most individuals of the other species found in the cankers were present in aggregations of *T. rhenanus* their habits are apparently similar. Three species were sometimes found in the same aggregation. A disproportionate number of *T. pyri* were found running about in the cankers; hibernating mites of this species are quickly aroused by warmth and leave their hibernation sites, whereas those of *T. rhenanus* may remain torpid for several hours in a warm room. In April, near the end of the normal hibernation period, all species usually become active soon after exposure to warmth.

In the dead bark of the trunks some phytoseiids were hibernating in cavities, but most of those found on both dead and living bark, being *T. pyri*, were active and their hibernation sites could not be located.

Small numbers of *T. rhenanus* were found in the splintered ends of broken branches and in deep crevices of pruning stubs. None were found in superficially rough areas of living bark on the limbs.

To determine whether the cankers supported a breeding population of phytoseiids during the summer, 16 cankers from the Boothman orchard with areas totalling 69 sq. in. were examined in June, July, and August, 1955, and September, 1958. Only two unidentified phytoseiids were found.

Twigs.—From 1951 to 1955, samples of one- to three-year-old twigs were collected each winter from one or more of the orchards and carefully examined for all forms of animal life. Only four or five phytoseiids, mostly *T. rhenanus*, were found on the approximate total of 2,000 ft. of twig. However, small cankers containing *T. rhenanus* were sometimes present on two- and three-year-old twigs.

Old Lecanium Scales.—In one of the cankers from the Janzen orchard in 1955-56, 217 phytoseiids were found beneath a single spent female of *Lecanium* sp. This observation led to the examination of old scales on the twigs in the same plot. A collection of prunings on March 12, 1956, yielded 130 scales of which 83 contained from one to 165 phytoseiids with a total of 1,452. Among 800 identified specimens, 790 were *T. rhenanus*, one *T. longipilus*, one *T. fallacis*, and eight *T. andersoni*. A rough estimation of the relative numbers of scales and cankers in this plot showed that by far the greater part of the phytoseiid population overwintering on the trees was beneath the scales.

In the Troup orchard, a sample of 109 scales, of which 38 contained mites, was collected on January 20, and one of 58 scales, 32 containing mites, on March 10, 1958. Numbers of living and dead mites of different species of *Typhlodromus* were as follows:

	January 20		March 10	
	Living	Dead	Living	Dead
T. conspicuus	20	0	35	0
T. elongatus	90	17	24	32
T. fallacis	30	57	7	199
T. longipilus	1	1	0	3
T. finlandicus	1	0	0	0
T. rhenanus	0	0	3	0

The mites occupied the cavity beneath the scale, having entered through the space at the end of the anal cleft through which the hatched scale crawlers emerge, and also the cavities formed by parasites within the body of the scale, the mites entering through the parasite exit holes on the dorsum.

Soil and Ground Cover.—On March 28, 1954, about two quarts of a thin layer of litter composed of fallen leaves, broken dead grass, etc., were collected in the Victoria orchard and extracted in Berlese funnels. Six *T. fallacis*, 19 *T. cucumeris*, and eight *T.* spp. were recovered. Operation of the funnels had not been perfected at that time and all of the mites were probably not recovered.

On April 6, 1955, 25 samples, each consisting of a 3-by-3 in. square of surface soil one-half in. deep with any superimposed litter, were taken within two ft. of the trunks of the trees in the same plot and extracted in Berlese funnels. They yielded totals of 19 *T. cucumeris*, one *T. fallacis*, and one *T. rhenanus*.

On April 30 and May 13, 1954, samples of chickweed weighing from 57 to 86 gm. from each of the six plots in the Janzen orchard were examined by washing in alcohol. The numbers of *T. fallacis* per plot, calculated on a uniform basis of 50 gm. of weed, on April 30 and May 13 respectively were 46 and 33, 17 and 23, 30 and 46, 51 and 36, 24 and 27, and 26 and 27. Some of the plots had received DDT and/or sulphur for several preceding summers, but there was no consistent correlation between spray treatment and the numbers of *T. fallacis*.

All of the *T. fallacis* recovered on April 30 were adult females, which had apparently hibernated in the soil or litter, but a few nymphs were present by May 13.

The collection of May 13 from the plot that had not been sprayed with DDT or sulphur also contained one *T. rhenanus* and 12 *T.* spp.

Small collections of weeds with an aggregate weight of about 200 gm. taken at irregular intervals in May, 1954, in the Victoria orchard yielded seven *T. fallacis*, five *T. cucumeris*, one *T. rhenanus*, two *T. pyri*, and 13 *T.* spp.

Winter Mortality.—Little information on winter mortality of the mites was obtained except for those in the *Lecanium* samples from the Troup orchard in 1958, where very high mortality of *T. fallacis* occurred. The minimum temperature during that winter at Vineland Station, four miles from the orchard, was -2.4°F., which had been exceeded in 15 of the previous 33 winters. In the cankers examined in March of 1954 and 1955, an estimated 30 to 60 per cent of *T. rhenanus* were dead.

Experiment with Cocoons of the Oriental Fruit Moth.—Of a total of 20 cardboard pieces of each type, 17 of those bearing cocoon walls had a total of 97 phytoseiids, whereas six of those without cocoons bore a total of 17 mites. When the data were subjected to a chi-square test of independence, the difference was significant at the 0.1 per cent level. Only 20 mites were on the cloth between the strips, although the area of cloth was much the greater. Nearly all the mites were *T. rhenanus*.

Discussion

It is evident that in peach orchards, *T. rhenanus* hibernated almost exclusively in cankers on the limbs of the trees, or under old *Lecanium* scales. *T. pyri*, found in relatively small numbers, was more uniformly dispersed over the trees, including the trunks. *T. finlandicus* occurred only in cankers and scales. Few or none of these species were found on the ground. *T. andersoni* has a wide range of hibernation sites, occurring in small numbers in all situations on the trees; some of the phytoseiids collected from chickweed in 1954, before this species was described, and listed in the preceding account as *T.* spp., were also *T. andersoni*, but a related species was also collected from similar sites and the relative numbers of the two species in the collections cannot now be determined.

The relative abundance of the foregoing species was roughly similar in both the populations hibernating on the trees and their summer populations on the twigs and foliage in the same orchards. On the other hand, the numbers of *T. fallacis* hibernating on the trees were relatively much smaller than would be expected from their numbers on the foliage; this species was nearly absent from cankers and scarce on the trunks, and must hibernate chiefly in litter or possibly in the soil. Although it was relatively abundant in the Janzen orchard on chickweed in the spring, it is not likely to have hibernated on the weed itself, for the overwintering plants were very small. In the Victoria orchard the numbers of *T. fallacis* on the trees during the summer were very small; nevertheless a few of this species were present in most of the soil and litter samples in the winter. Although most individuals of this species hibernate on the ground, the presence of dead *Lecanium* scales may apparently induce some to enter hibernation on the trees, but as shown by the scale samples from the Troup orchard they suffer very high winter mortality in these sites.

T. cucumeris inhabits chiefly litter and low vegetation throughout the year, according to observations of the writer; very few have ever been taken on peach

foliage. Some of the small numbers hibernating on the trunks may have ascended them in the fall.

T. conspicuus and *T. guatemalensis* hibernated both in cankers and under *Lecanium* scales; whether they hibernate elsewhere is unknown, for no samples were taken from the trunks or ground in those orchards where these usually uncommon species occurred in greatest numbers. *T. longipilus*, another uncommon species, was taken too seldom to warrant any conclusion beyond the fact that it may sometimes hibernate on the trees.

The many acarids and other minute saprophagous mites in cankers might be expected to support an indigenous population of phytoseiids, but the latter were shown to be nearly absent from cankers in summer and consequently those hibernating there must be derived from the population breeding on the leaves and twigs.

In cankers, the most important physical properties that make a site suitable for hibernation appeared to be dryness, darkness, and a narrow space to satisfy the thigmotactic responses of the mites. The sites beneath or within dead scale insects have the same properties except darkness, for the scales are translucent.

The very common occurrence of the mites in cocoons, exuviae, and dead bodies of insects suggests a chemotactic response to materials of animal origin. This hypothesis is strengthened by the definite attraction shown by the pieces of oriental fruit moth cocoons experimentally placed on the trees. The cocoons of the non-diapause larvae used were of a very thin and scarcely visible layer of silk which would scarcely modify the physical character of the fibrous strawboard on which it was spun.

The groups formed by hibernating mites are probably social aggregations as defined by Ellis (1953), formed through interactions between individuals, for the few occupied sites, except those in insect remains, are unlikely to have unique physicochemical properties differing from many other situations in the cankers. The stimuli promoting these aggregations may possibly be the same as those leading to the concentration of the mites on non-living animal substances.

Summary

In Ontario peach orchards, *Typhlodromus rhenanus* hibernates chiefly in cankers on the limbs, *T. pyri* in cankers and on the trunks, *T. andersoni* on both trees and ground litter, and *T. fallacis* and *T. cucumeris* chiefly in litter or soil. All species hibernating on the trees, except *T. cucumeris*, also occupy dead scales of *Lecanium* spp. Hibernating phytoseiids usually occur in groups, sometimes of two or three species, which may be social aggregations. Cocoons of Lepidoptera and their contained insect remains, and cavities in or under dead scale insects, were among the sites most frequently occupied. An experiment showed that the mites were attracted to fragments of oriental fruit moth cocoons.

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Note on a Method of Comparing Diets for the Pale Western Cutworm, *Agrotis orthogonia* Morr. (Lepidoptera: Noctuidae)[1]

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The pale western cutworm, *Agrotis orthogonia* Morr., has been successfully reared in the laboratory on a number of different foods (Jacobson and Blakeley, 1958; McGinnis and Kasting, 1959). Initial evaluation of the nutritional adequacy of diets for the cutworm has been achieved by comparing growth curves based on mean weights of the groups of larvae on test (McGinnis and Kasting, 1959). This note shows that the relative value of diets for the larvae of the pale western cutworm can be established more simply by comparing growth curves based on mean weights recorded two days after each moult.

The mean weights of the larvae were computed for several diets on the day of moulting and on the first, second, and third days thereafter. The nutritional efficiency of the diets varied from excellent (wheat sprouts) to poor (reconstituted wheat stems). The latter diet was incapable of supporting the growth of newly hatched larvae. For comparing diets, curves based on one mean weight per instar should represent the detailed growth curves. For any instar it was assumed that the most suitable weight for the simplified growth curve would be the mean on that day when the variability of weights within the population was least.

Table I.
Mean weights (mg.) and coefficients of variability of larvae fed on various diets, at different times during the larval period.

Diet	No. of insects	Instar	Days after moult							
			0		1		2		3	
			Wt.	C.V.[1]	Wt.	C.V.	Wt.	C.V.	Wt.	C.V.
Thatcher wheat sprouts (*ad libitum*)	9	4	27	(14.6)	40	(11.0)	67	(8.7)	96	(12.4)
	9	5	118	(10.3)	171	(10.1)	197	(9.1)	245	(8.6)
	9	6	389	(18.6)	424	(10.4)	467	(10.1)	518	(9.6)
Thatcher wheat sprouts (available 2 hr./day)	16	4	27	(13.8)	35	(16.2)	43	(14.9)	51	(15.8)
	16	5	64	(25.7)	88	(19.8)	106	(18.0)	119	(19.1)
	16	6	171	(23.0)	207	(16.0)	234	(14.7)	265	(14.9)
	16	7	331	(16.5)	413	(12.4)	450	(12.0)	483	(12.9)
Leaf[2]: cellulose: water (3:1:8)	12	3	5	(27.3)	10	(28.8)	15	(23.5)		
	12	4	25	(30.5)	41	(33.9)	52	(35.9)		
	11	5	68	(21.8)	92	(15.0)	144	(13.3)		
	11	6	246	(19.4)	335	(15.8)	390	(16.1)		
Leaf[2]: cellulose: water (1:3:8)	14	3	4	(23.1)	7	(24.6)	10	(29.5)		
	13	4	17	(35.0)	25	(37.3)	36	(29.3)		
	14	5	52	(26.7)	73	(26.3)	102	(25.1)		
	14	6	140	(31.4)	174	(25.4)	194	(27.7)		
Stem[3]: water (1:2)	16	5	173	(25.1)	210	(20.6)	233	(17.4)	252	(22.2)

[1]Coefficient of variability
[2]Lyophilized 10-day old Thatcher leaf meal
[3]Lyophilized 9-week-old Thatcher stem meal

[1]Contribution from the Entomology Section and the Chemistry Section.

Despite the variations of mean weights of populations with stage of development and diet, the coefficients of variability (Goulden, 1939), with few exceptions, were the smallest on the second day after moulting (Table I). Because observations were made only once each day a moult may have occurred at any time in the 24-hour period prior to its being recorded. As larvae commence feeding extensively within a few hours after moulting, they could increase greatly in weight between the actual time of moulting and the time the larvae were weighed. No doubt this condition contributed materially to the larger coefficients of variability on the day of moulting. The weights became more uniform after the larvae had fed for a day or two, but beyond the second day there was a tendency for the variability in larval weights to increase.

Curves based on mean weights taken two days after each moult were compared with those based on daily weights. Such a comparison for several diets showed that larval development was described equally well by either curve, although some detail was necessarily lost in the simplified curves. Thus it is evident that diets for the pale western cutworm can be compared satisfactorily by weighing larvae on the second day after each moult when increase in weight is the criterion of nutritional adequacy.

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Note on *Coelomomyces psorophorae* Couch, a Fungus Parasitic on Mosquito Larvae[1]

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In the irrigated districts of southern Alberta larvae of *Culiseta inornata* (Williston) were found to be infected with the fungus *Coelomomyces psorophorae* Couch, identified by J. N. Couch, Department of Botany, University of North Carolina. This is the first record on *C. inornata* in Canada.

The resting sporangia (Fig. 1) were found in the thoracic and abdominal cavities of the larvae. The infected larvae were darker brown in color, larger in size, and slower in movement than the non-infected ones.

The infected larvae were first discovered at Brooks, Alberta, on August 8, 1956, and the following year were taken in weekly samples in all irrigated districts from July 8 to September 3. This fungus is widely distributed and well established in southern Alberta. Its occurrence is not merely incidental, because

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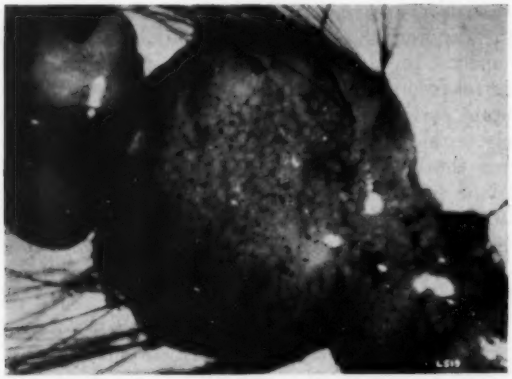

Fig. 1. The resting sporangia of *Coelomomyces psorophorae* in the thoracic and abdominal cavity of fourth-instar larva of *C. inornata*.

12 per cent of all larvae of *C. inornata* examined were infected. It has not been found on any other species of mosquito in this area, but Couch and Dodge (1947) reported finding it on larvae of *Aedes vexans* (Meigen) and *Psorophora ciliata* (Fabricius) as well as *C. inornata*. This extended the northern limits into Georgia and South Carolina. Our record extends the range as far as 50° 35′ N.

Hearle (1929) reported yellow opaque bodies, which might have been *Coelomomyces* sp., in the abdominal cavity of one dead female of *Aedes flavescens* (Müller). Although Couch and Dodge (1947) considered fungal infection of little economic importance in reducing mosquito populations, Muspratt (1946) in Rhodesia estimated that *Coelomomyces* caused 95 per cent mortality in *Anopheles gambiae* Giles from 1941 to 1945. The pathogenicity of *C. psorophorae* to larvae, pupae, and adults of *C. inornata* is being investigated further.

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